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(54) **EXEMPLAR-BASED NATURAL LANGUAGE PROCESSING**

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(58) **Field of Classification Search**
None
See application file for complete search history.

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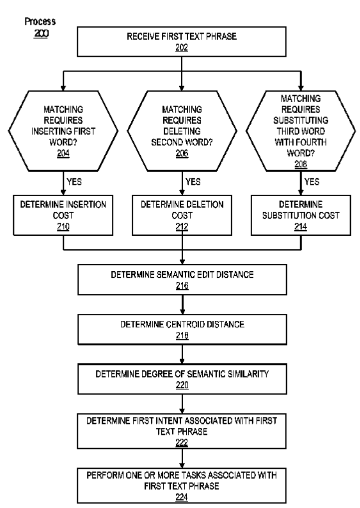
(57) **ABSTRACT**

Systems and processes for exemplar-based natural language processing are provided. In one example process, a first text phrase can be received. It can be determined whether editing the first text phrase to match a second text phrase requires one or more of inserting, deleting, and substituting a word of the first text phrase. In response to determining that editing the first text phrase to match the second text phrase requires one or more of inserting, deleting, and substituting a word of the first text phrase, one or more of an insertion cost, a deletion cost, and a substitution cost can be determined. A semantic edit distance between the first text phrase and the second text phrase in a semantic space can be determined based on one or more of the insertion cost, the deletion cost, and the substitution cost.

19 Claims, 10 Drawing Sheets



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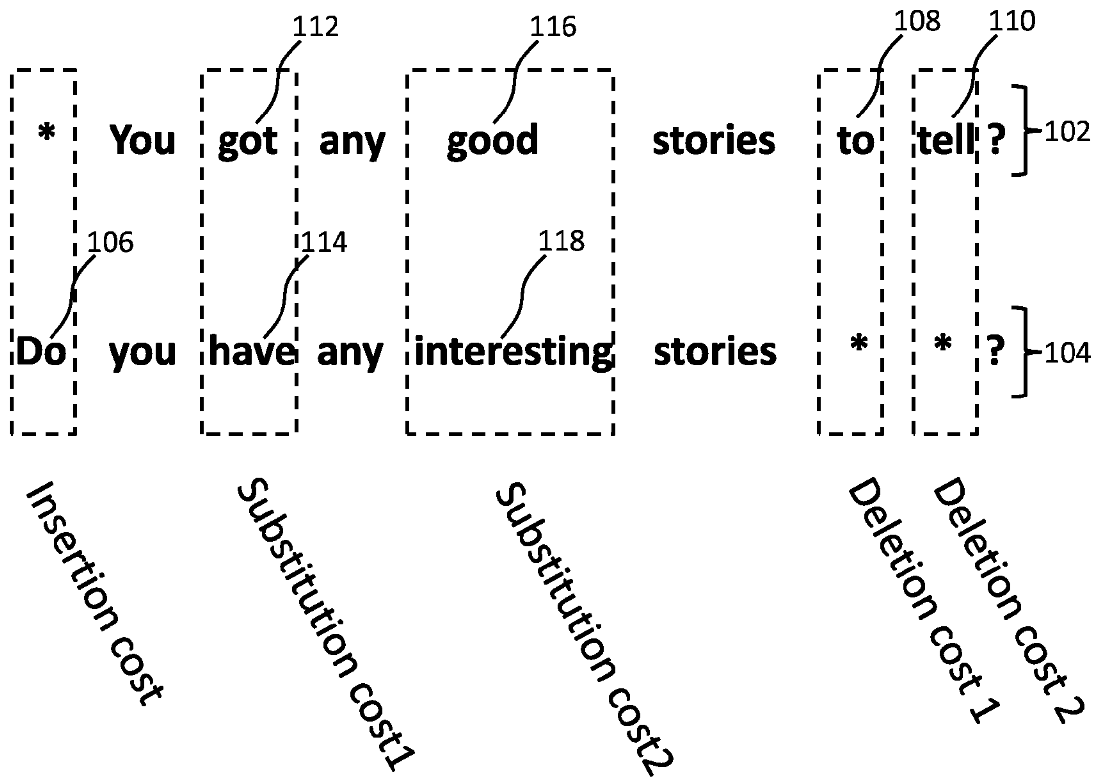
112
116
108
110
* You got any good stories to tell ?
102
106
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Do you have any interesting stories * * ?
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Deletion cost 2

FIG. 1

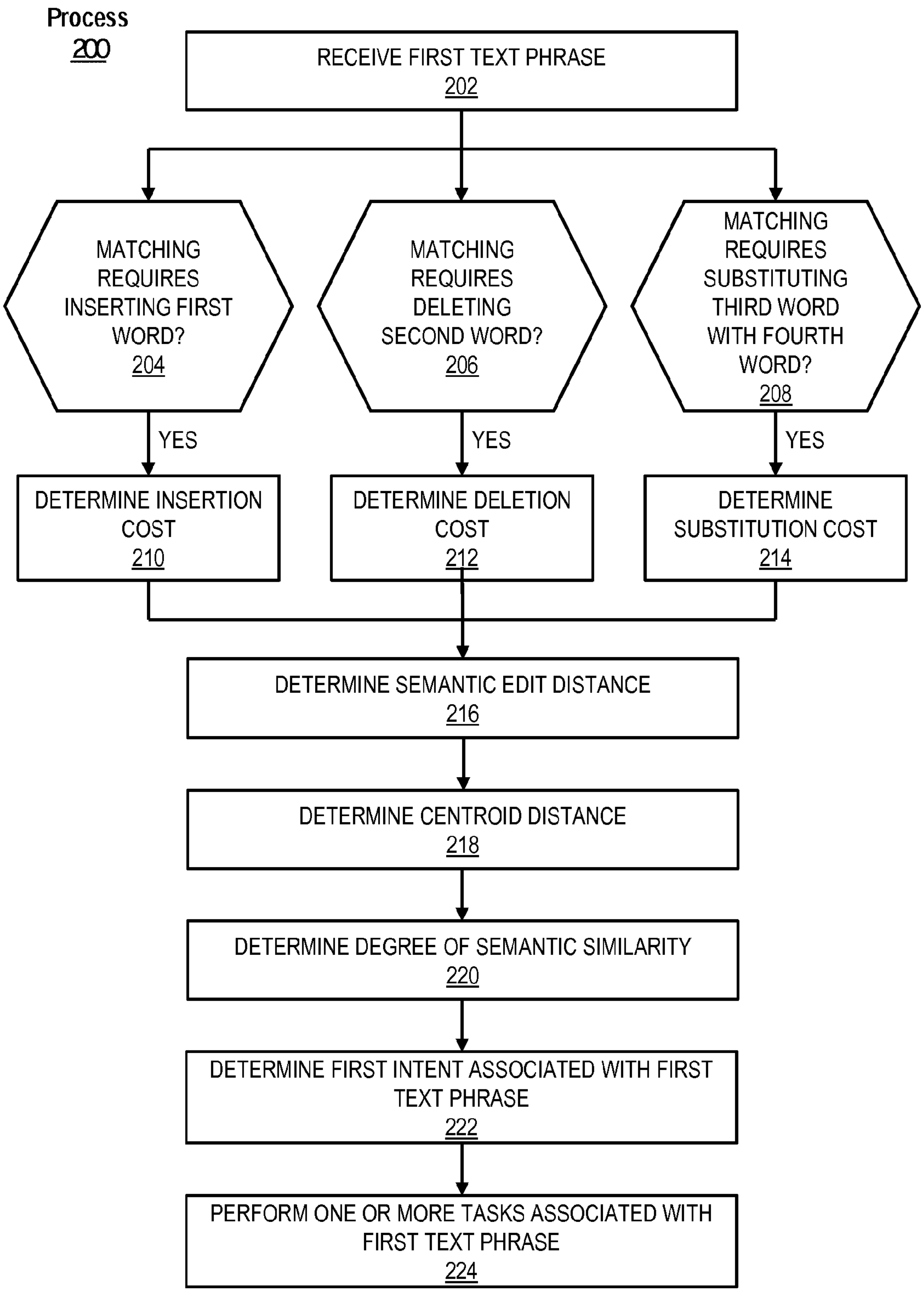

Process
200
RECEIVE FIRST TEXT PHRASE
202
MATCHING REQUIRES INSERTING FIRST WORD?
204
MATCHING REQUIRES DELETING SECOND WORD?
206
MATCHING REQUIRES SUBSTITUTING THIRD WORD WITH FOURTH WORD?
208
YES
YES
YES
DETERMINE INSERTION COST
210
DETERMINE DELETION COST
212
DETERMINE SUBSTITUTION COST
214
DETERMINE SEMANTIC EDIT DISTANCE
216
DETERMINE CENTROID DISTANCE
218
DETERMINE DEGREE OF SEMANTIC SIMILARITY
220
DETERMINE FIRST INTENT ASSOCIATED WITH FIRST TEXT PHRASE
222
PERFORM ONE OR MORE TASKS ASSOCIATED WITH FIRST TEXT PHRASE
224

FIG. 2

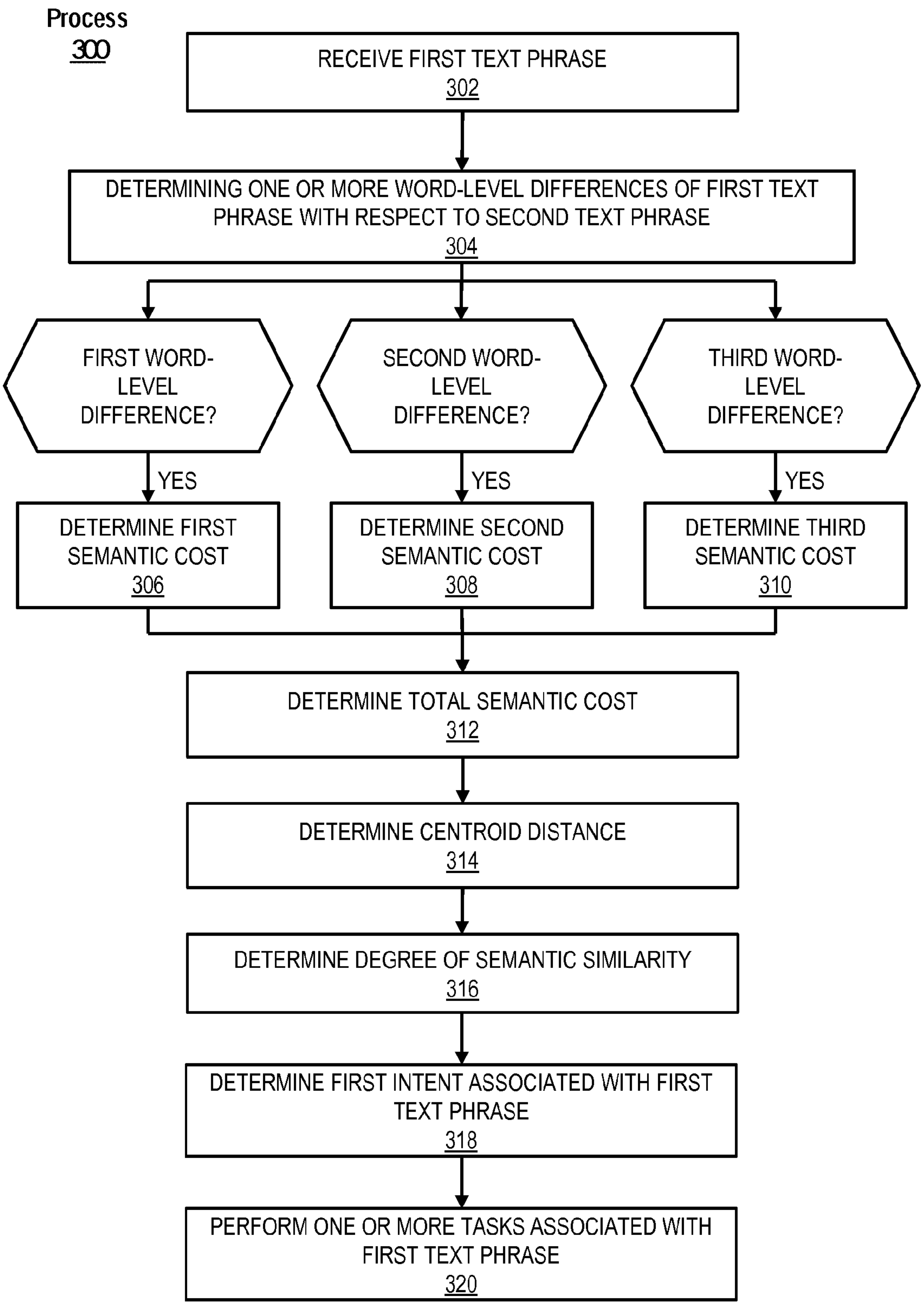

Process
300
RECEIVE FIRST TEXT PHRASE
302
DETERMINING ONE OR MORE WORD-LEVEL DIFFERENCES OF FIRST TEXT PHRASE WITH RESPECT TO SECOND TEXT PHRASE
304
FIRST WORD-LEVEL DIFFERENCE?
SECOND WORD-LEVEL DIFFERENCE?
THIRD WORD-LEVEL DIFFERENCE?
YES
YES
YES
DETERMINE FIRST SEMANTIC COST
306
DETERMINE SECOND SEMANTIC COST
308
DETERMINE THIRD SEMANTIC COST
310
DETERMINE TOTAL SEMANTIC COST
312
DETERMINE CENTROID DISTANCE
314
DETERMINE DEGREE OF SEMANTIC SIMILARITY
316
DETERMINE FIRST INTENT ASSOCIATED WITH FIRST TEXT PHRASE
318
PERFORM ONE OR MORE TASKS ASSOCIATED WITH FIRST TEXT PHRASE
320

FIG. 3

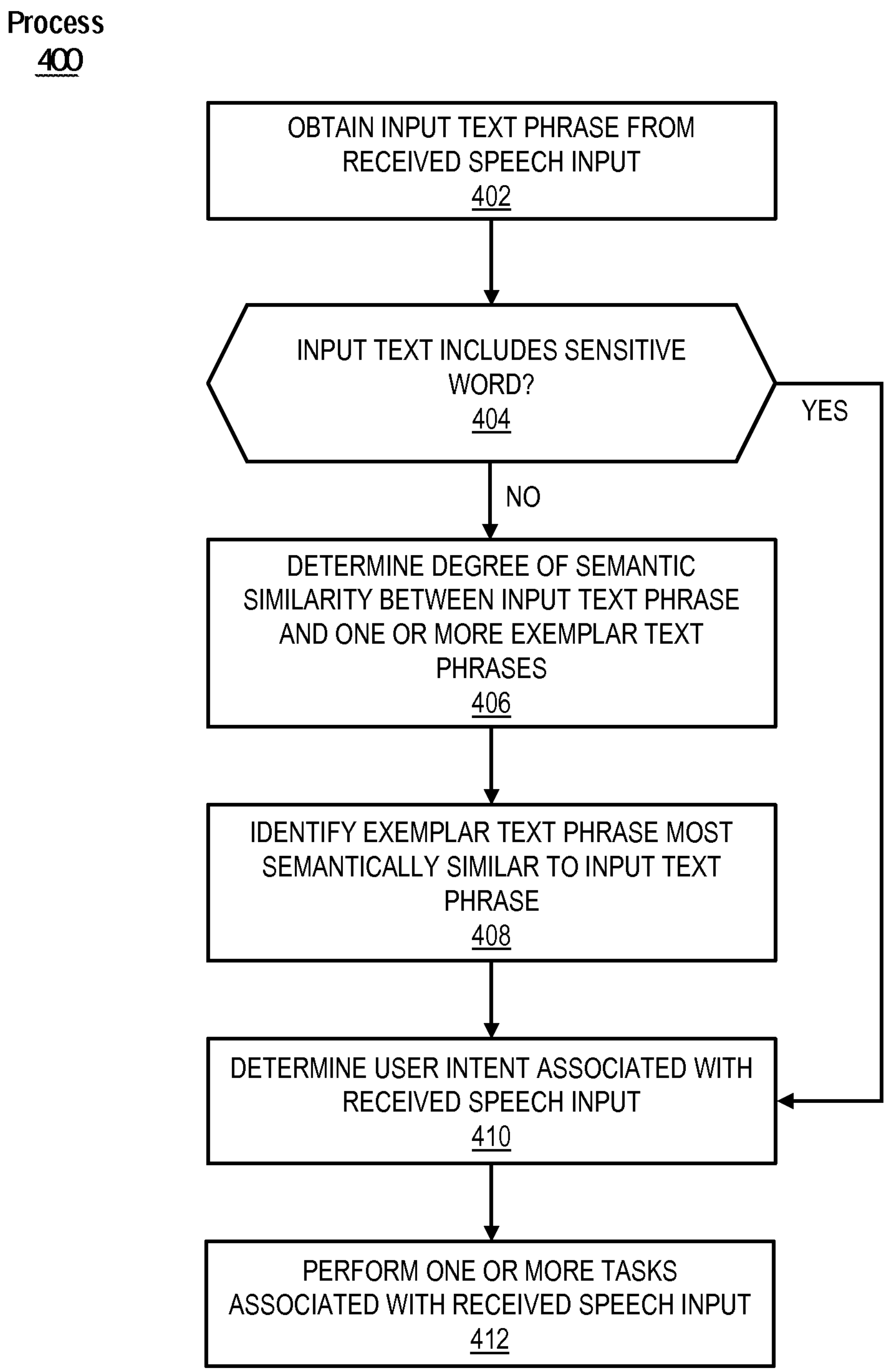

Process
400
OBTAIN INPUT TEXT PHRASE FROM RECEIVED SPEECH INPUT
402
INPUT TEXT INCLUDES SENSITIVE WORD?
404
YES
NO
DETERMINE DEGREE OF SEMANTIC SIMILARITY BETWEEN INPUT TEXT PHRASE AND ONE OR MORE EXEMPLAR TEXT PHRASES
406
IDENTIFY EXEMPLAR TEXT PHRASE MOST SEMANTICALLY SIMILAR TO INPUT TEXT PHRASE
408
DETERMINE USER INTENT ASSOCIATED WITH RECEIVED SPEECH INPUT
410
PERFORM ONE OR MORE TASKS ASSOCIATED WITH RECEIVED SPEECH INPUT
412

FIG. 4

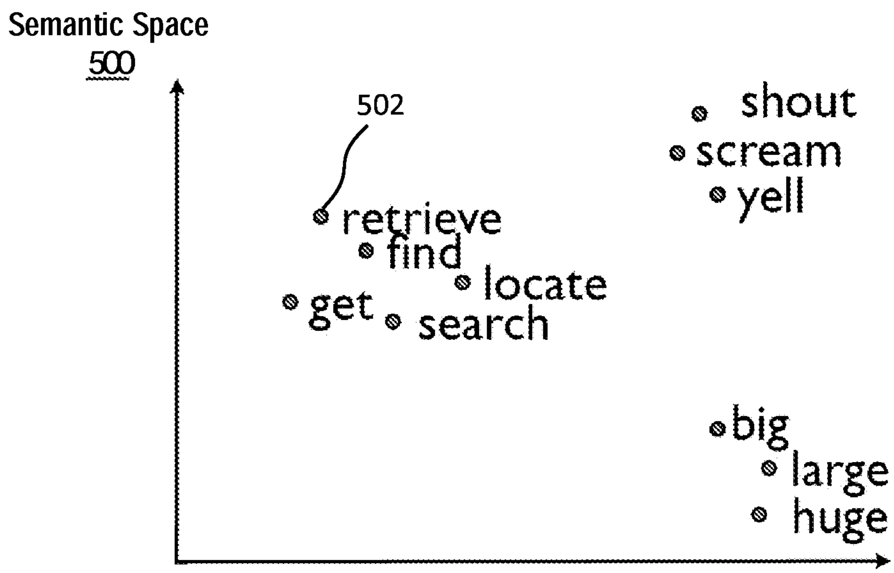

Semantic Space
500
502
retrieve
find
locate
get
search
shout
scream
yell
big
large
huge

FIG. 5

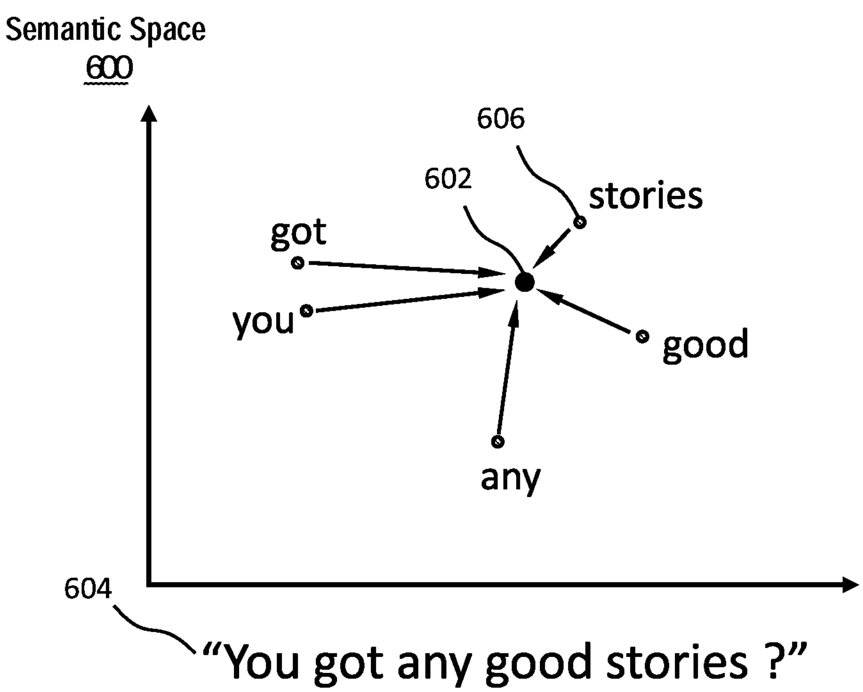

Semantic Space
600
606
602
stories
got
you
good
any
604
"You got any good stories ?"

FIG. 6

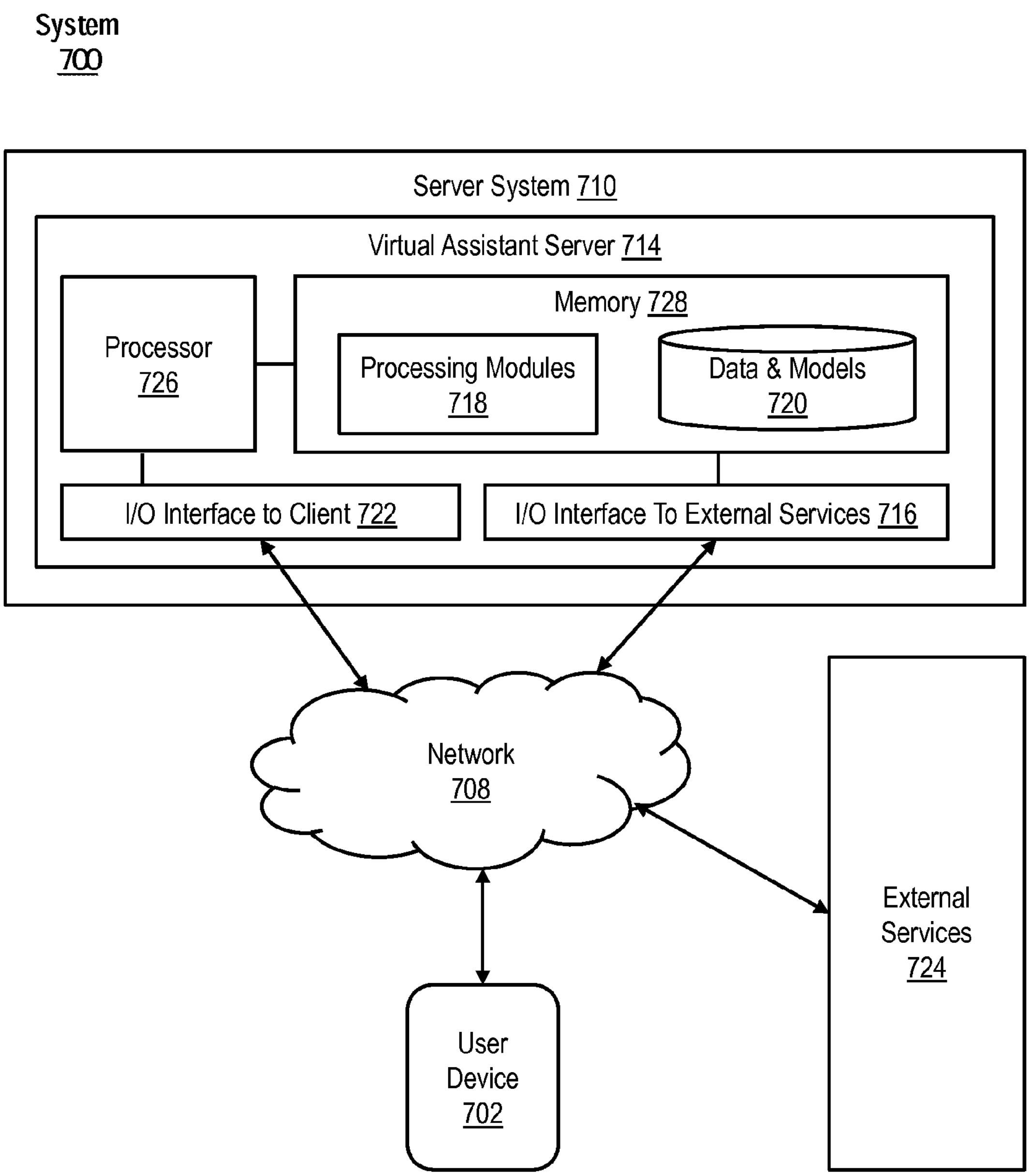

System
700
Server System 710
Virtual Assistant Server 714
Processor
726
Memory 728
Processing Modules
718
Data & Models
720
I/O Interface to Client 722
I/O Interface To External Services 716
Network
708
External
Services
724
User
Device
702

FIG. 7

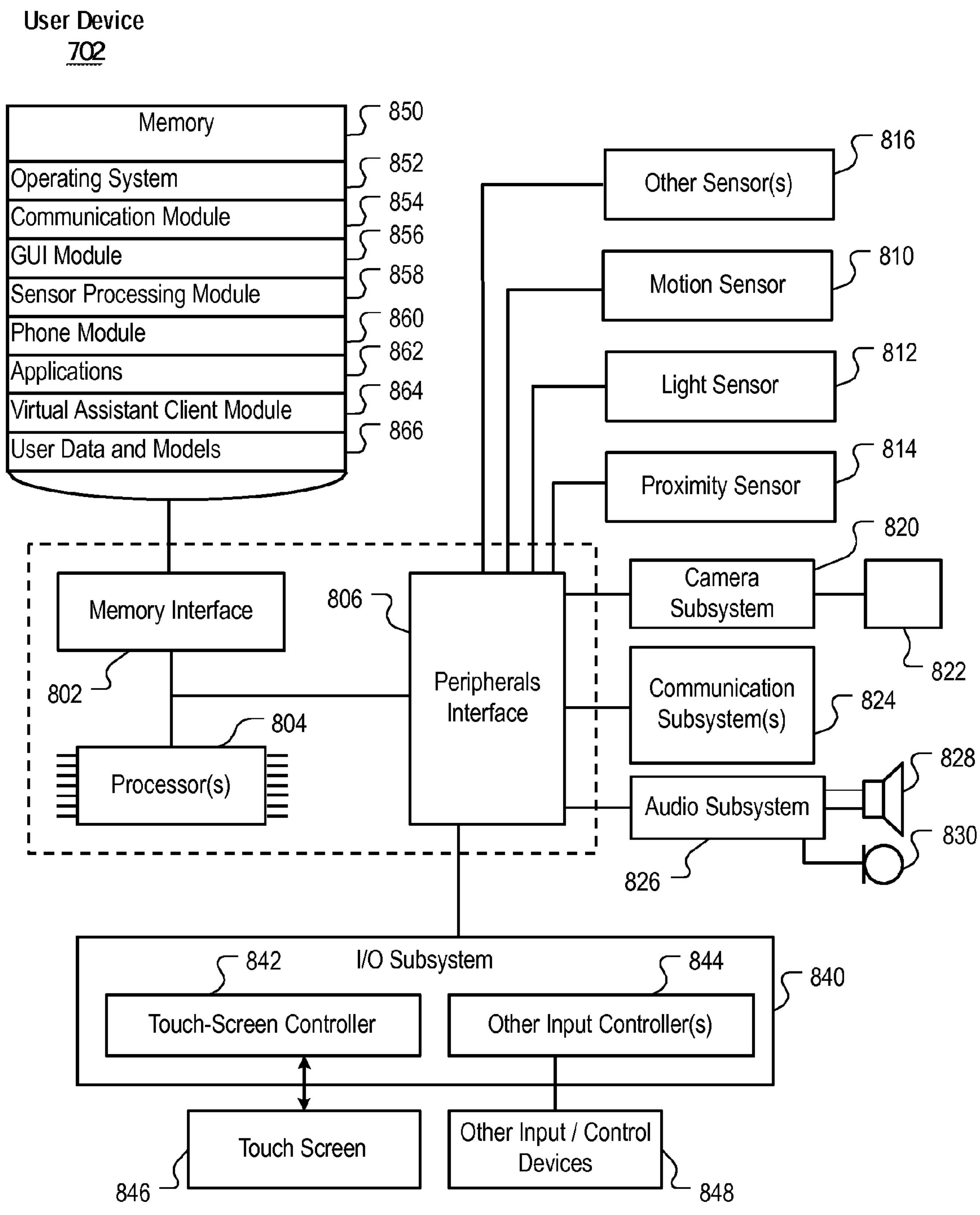

User Device
702
Memory
850
Operating System
852
Communication Module
854
GUI Module
856
Sensor Processing Module
858
Phone Module
860
Applications
862
Virtual Assistant Client Module
864
User Data and Models
866
Other Sensor(s)
816
Motion Sensor
810
Light Sensor
812
Proximity Sensor
814
Camera Subsystem
820
822
Memory Interface
802
806
Peripherals Interface
Processor(s)
804
Communication Subsystem(s)
824
Audio Subsystem
826
828
830
I/O Subsystem
840
Touch-Screen Controller
842
Other Input Controller(s)
844
Touch Screen
846
Other Input / Control Devices
848

FIG. 8

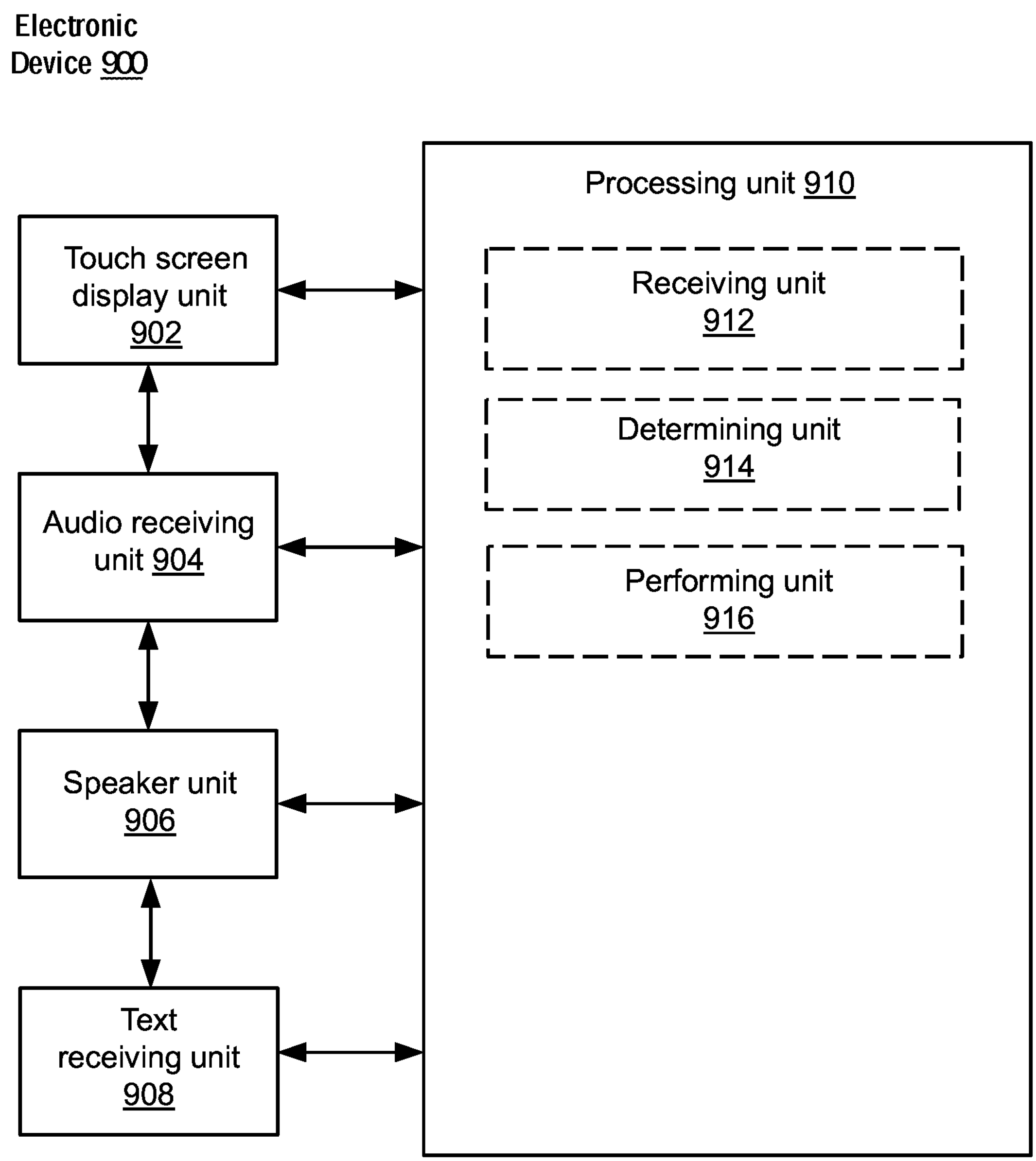

Electronic
Device 900
Processing unit 910
Touch screen
display unit
902
Receiving unit
912
Determining unit
914
Audio receiving
unit 904
Performing unit
916
Speaker unit
906
Text
receiving unit
908

FIG. 9

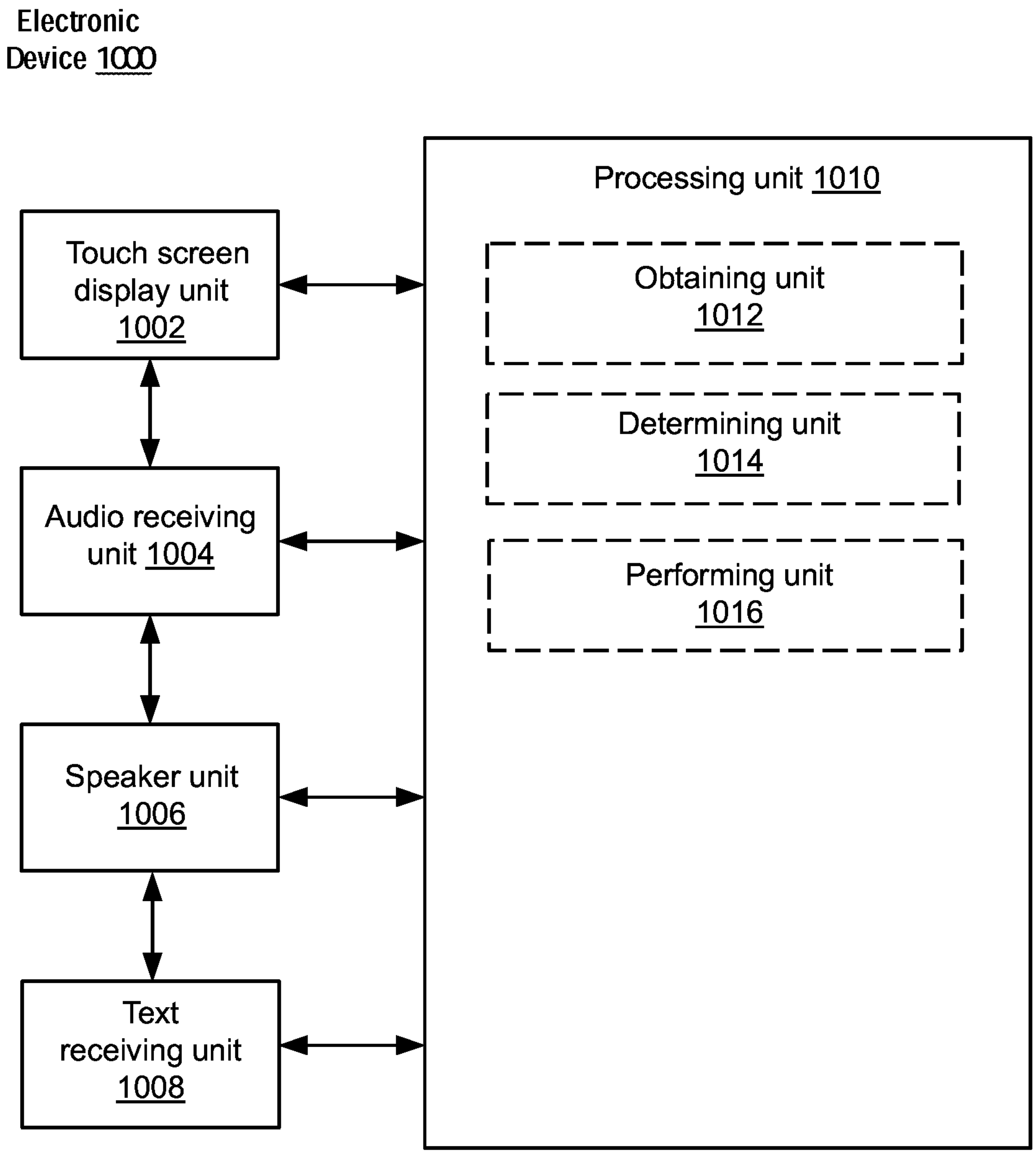
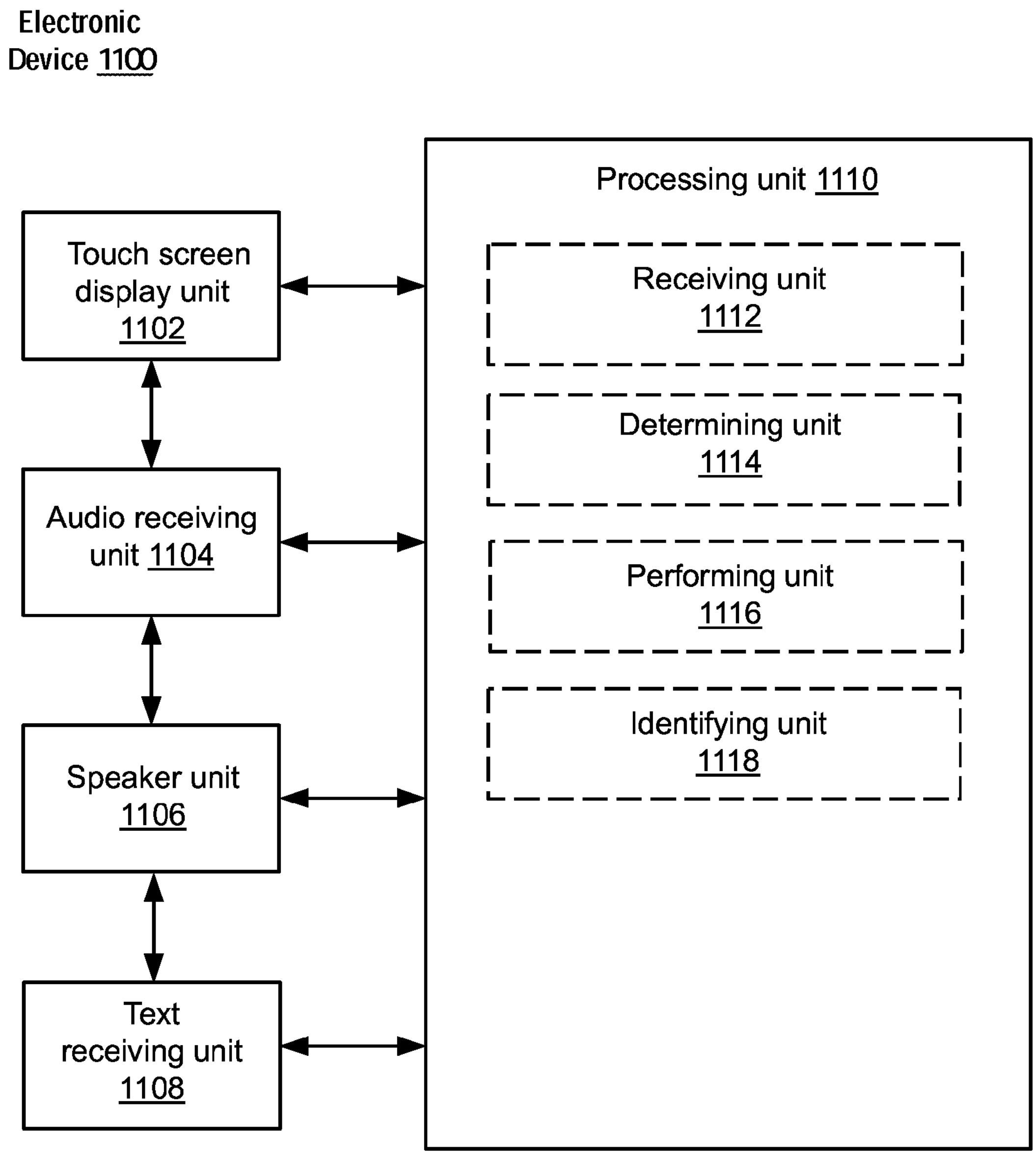

Electronic
Device 1000
Processing unit 1010
Touch screen
display unit
1002
Obtaining unit
1012
Determining unit
1014
Audio receiving
unit 1004
Performing unit
1016
Speaker unit
1006
Text
receiving unit
1008

FIG. 10



Electronic Device 1100
Processing unit 1110
Touch screen display unit 1102
Receiving unit 1112
Determining unit 1114
Audio receiving unit 1104
Performing unit 1116
Identifying unit 1118
Speaker unit 1106
Text receiving unit 1108

FIG. 11

EXEMPLAR-BASED NATURAL LANGUAGE PROCESSING

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority from U.S. Provisional Ser. No. 62/005,786, filed on May 30, 2014, entitled EXEMPLAR-BASED NATURAL LANGUAGE PROCESSING, which is hereby incorporated by reference in its entirety for all purposes.

FIELD

This relates generally to natural language processing and, more specifically, to exemplar-based natural language processing.

BACKGROUND

Natural language input can be written or spoken input (e.g., speech or text) that is in a natural form used by a person when speaking or writing to another person. Natural language input can permit a user to easily interact with an electronic device using well-known language. For example, a virtual assistant operating on an electronic device can enable a user to access various services of the electronic device through natural language input to the virtual assistant. The virtual assistant can perform natural language processing on the natural language input to determine user intent from the natural language input. The determined user intent can then be operationalized into tasks that are executed by the virtual assistant.

Natural language processing can be implemented by parsing and recognizing individual words or groups of words in the natural language input to determine the user intent associated with the input. However, due to the complex and shifting "rules" of human natural language, the overall meaning of a natural language input can be missed by recognizing small portions of natural language input separately. In addition, a given user intent can be expressed in many unanticipated ways using natural language. According, determining user intent by recognizing small portions of natural language input separately can yield inaccurate or incomplete results.

SUMMARY

Systems and processes for exemplar-based natural language processing are provided. In one example process, a first text phrase can be received. It can be determined whether editing the first text phrase to match a second text phrase requires one or more of inserting a first word into the first text phrase, deleting a second word from the first text phrase, and substituting a third word of the first text phrase with a fourth word. The second text phrase can include the first word, the first text phrase can include the second word, and the second text phrase can include the fourth word. In response to determining that editing the first text phrase to match the second text phrase requires one or more of inserting the first word into the first text phrase, deleting the second word from the first text phrase, and substituting the third word of the first text phrase with the fourth word, one or more of an insertion cost, a deletion cost, and a substitution cost can be determined. It can be determined, based on the one or more of the insertion cost, the deletion cost, and the substitution cost, a semantic edit distance between the first text phrase and the second text phrase in a semantic space. A degree of semantic similarity between the first text phrase and the second text phrase can be based on the semantic edit distance.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates the comparison of an example first text phrase to an example second text phrase for exemplar-based natural language processing according to various examples.

FIG. **2** illustrates an exemplary process for exemplar-based natural language processing according to various examples.

FIG. **3** illustrates an exemplary process for exemplar-based natural language processing according to various examples.

FIG. **4** illustrates an exemplary process for exemplar-based natural language processing of speech according to various examples.

FIG. **5** illustrates an exemplar semantic space according to various examples.

FIG. **6** illustrates a centroid position of an exemplar text phrase in a semantic space according to various examples.

FIG. **7** illustrates an exemplary system and environment for carrying out aspects of exemplar-based natural language processing according to various examples.

FIG. **8** illustrates an exemplary user device for carrying out aspects of exemplar-based natural language processing according to various examples.

FIG. **9** illustrates a functional block diagram of an exemplary electronic device according to various examples.

FIG. **10** illustrates a functional block diagram of an exemplary electronic device according to various examples.

FIG. **11** illustrates a functional block diagram of an exemplary electronic device according to various examples.

DETAILED DESCRIPTION

In the following description of examples, reference is made to the accompanying drawings in which it is shown by way of illustration specific examples that can be practiced. It is to be understood that other examples can be used and structural changes can be made without departing from the scope of the various examples.

The present disclosure relates to exemplar-based natural language processing. According to various examples described herein, exemplar-based natural language processing can be used to determine a user intent associated with an input text phrase by matching the input text phrase to a set of exemplar text phrases that are each associated with a predetermined intent. For example, the exemplar text phrase, "Where can I get money?" can be associated with the predetermined intent of finding a bank or an automatic teller machine (ATM). The input text phrase, "Where can I get some cash?" can be matched to the exemplar text phrase. Thus, the user intent associated with the input text phrase can be determined to be similar or identical to the predetermined intent associated with the exemplar text phrase.

In one example process, an input text phrase can be matched to the exemplar-text phrase by determining a degree of semantic similarity between the input text phrase and the exemplar text phrase. In this example, the input text phrase can be received. It can be determined whether editing the input text phrase to match an exemplar text phrase requires one or more of inserting a first word into the input text phrase, deleting a second word from the input text phrase, and substituting a third word of the input text phrase with a fourth word. The exemplar text phrase can include the first word, the input text phrase can include the second word, and the exemplar text phrase can include the fourth word. In response to determining that editing the input text phrase to match the exemplar text phrase requires one or more of inserting the first word into the input text phrase, deleting the second word from the input text phrase, and substituting the third word of the input text phrase with the fourth word, one or more of an insertion cost, a deletion cost, and a substitution cost can be determined. A semantic edit distance between the input text phrase and the exemplar text phrase in a semantic space can be determined based on one or more of the insertion cost, the deletion cost, and the substitution cost. The degree of semantic similarity between the input text phrase and the exemplar text phrase can be based on the semantic edit distance.

1. Exemplar-based Natural Language Processes

FIG. **1** illustrates the comparison of first text phrase **102** to second text phrase **104** for exemplar-based natural language processing according to various examples. FIG. **2** illustrates process **200** for exemplar-based natural language processing according to various examples. Process **200**, can be described with simultaneous reference to FIGS. **1** and **2**.

At block **202** of process **200**, first text phrase **102** can be received. First text phrase can be natural language text and can include a string of words. In this example, as shown in FIG. **1**, first text phrase **102** can include the question, "You got any good stories to tell?" In other examples, the first text phrase can be any request, statement, exclamation, question, or the like. In some examples, the first text phrase can be less than 150 characters. First text phrase **102** can include a first intent that can be determined using exemplar-based natural language processing.

First text phrase **102** can be received via an interface of a user device (e.g., touch screen **846** or other input/control devices **848** of user device **702**, described below). The interface can be any suitable device for inputting text. For example, the interface can be a keyboard/keypad, a touch screen implementing a virtual keyboard or a handwriting recognition interface, a remote control (e.g., television remote control), a scroll wheel interface, or the like. In some examples, first text phrase **102** can be received from a speech-to-text converter. In these examples, at least a portion of a received speech input can be transcribed into text via the speech-to-text converter. First text phrase **102** can include the transcribed text.

At blocks **204**, **206**, and **208** of process **200**, it can be determined whether editing first text phrase **102** to match second text phrase **104** requires one or more of: a) inserting a first word into the first text phrase, b) deleting a second word from the first text phrase, and c) substituting a third word of the first text phrase with a fourth word. Second text phrase **104** can include the first word, first text phrase **102** can include the second word, and second text phrase **104** can include the fourth word.

Second text phrase **104** can be a predetermined text phrase. For example, second text phrase **104** can be an exemplar text phrase stored on the user device or a remote system and can be associated with a predetermined intent and/or a predetermined task to be performed. In this example, second text phrase **104** can be the predetermined question, "Do you have any interesting stories?" In this example, second text phrase **104** can be associated with the predetermined intent of requesting a story and/or the predetermined task of retrieving a story. In other examples, second text phrase **104** can be any predetermined natural language text that includes a string of words. Like first text phrase **102**, second text phrase **104** can be any request, statement, exclamation, question or the like. In some cases, second text phrase **104** can also be less than 150 characters.

First text phrase **102** can be compared to second text phrase **104** to determine the types of edits that would be required in order for first text phrase **102** to match with second text phrase. In this example, second text phrase **104** can include first word "do" **106** for which first text phrase **102** does not include any corresponding word. Thus, at block **204**, it can be determined that editing first text phrase **102** to match second text phrase **104** would require inserting first word "do" **106** into first text phrase **102**.

In addition, first text phrase **102** can include second word "to" **108** for which second text phrase **104** does not include any corresponding word. Further, in this example, first text phrase **102** can include the word "tell" **110** for which second text phrase **104** does not include any corresponding word. Thus, at block **206**, it can be determined that editing first text phrase **102** to match second text phrase **104** would require deleting second word **108** "to" and the word "tell" **110** from first text phrase **102**.

Further, first text phrase **102** can include third word "got" **112** that is different from corresponding fourth word "have" **114** of second text phrase **104**. Similarly, first text phrase **102** can include the word "good" **116** that is different from corresponding word "interesting" **118** of second text phrase **104**. Thus, at block **208**, it can be determined that editing first text phrase **102** to match second text phrase **104** would require substituting third word "got" **112** with fourth word "have" **114** and substituting the word "good" **116** with the word "interesting" **118**.

At block **210** of process **200**, an insertion cost associated with inserting first word "do" **106** into first text phrase **102** can be determined in response to determining that editing first text phrase **102** to match second text phrase **104** requires inserting first word "do" **106** into first text phrase **102**. The insertion cost can be determined based on a first predetermined semantic cost and a salience of the first word. For example, the insertion cost, $cost_{ins}$("do")=i*salience("do"), where i denotes the first predetermined semantic cost and salience("do") denotes the salience of the word "do." Functions for deriving the salience of a given word, salience(w), are explained in greater detail below.

At block **212** of process **200**, a first deletion cost associated with deleting second word "to" **108** from first text phrase **102** can be determined in response to determining that editing first text phrase **102** to match second text phrase **104** requires deleting second word "to" **108** from first text phrase **102**. The first deletion cost can be determined based on a second predetermined semantic cost and a salience of second word "to" **106**. For example, the first deletion cost, $cost_{del}$("to")=d*salience("to"), where d denotes the second predetermined semantic cost and salience("to") denotes the salience of the word "to." In some examples, the first predetermined semantic cost is greater than the second predetermined semantic cost. This can be because inserting an additional word to a text phrase typically changes the semantics of the text phrase significantly. Therefore, the cost associated with inserting a word should be greater than the cost associated with deleting a word.

Further, a second deletion cost associated with deleting the word "tell" **110** from first text phrase **102** can be determined in response to determining that editing first text phrase **102** to match second text phrase **104** requires deleting the word "tell" **110** from first text phrase **102**. The second deletion cost can be determined in a similar or identical manner as the first deletion cost. For example, the second deletion cost, $cost_{del}$("tell")=d*salience("tell"), where salience("tell") denotes the salience of the word 'tell.'

At block **214** of process **200**, a first substitution cost associated with substituting third word "got" **112** of first text phrase **102** with fourth word "have" **114** can be determined in response to determining that editing first text phrase **102** to match second text phrase **104** requires substituting third word "got" **112** of first text phrase **102** with fourth word "have" **114**. The first substitution cost can be determined based on a salience of third word "got" **112**, a salience of fourth word "have" **114**, a semantic similarity between third word "got" **112** and fourth word "have" **114** in a semantic space, the first predetermined semantic cost, and the second predetermined semantic cost. For example, the first substitution cost:

$$cost_{sub}(\text{"got", "have"})=(cost_{del}(\text{"got"})+cost_{ins}(\text{"have"}))(1-\text{similarity}(\text{"got", "have"}))$$

where $cost_{del}$("got") denotes the deletion cost associated with deleting third word "got" **112** from first phrase **102**, $cost_{ins}$("have") denotes the insertion cost associated with inserting fourth word "have" **114** into first phrase **102**, and similarity("got", "have") denotes the semantic similarity between third word "got" **112** and fourth word "have" **114**. $Cost_{del}$("got") can be determined in a similar or identical manner as $cost_{del}$("tell") described above at block **212** and can be based on the second predetermined semantic cost and the salience of third word "got" **112**. $Cost_{ins}$("have") can be determined in a similar or identical manner as $cost_{ins}$("do") described above at block **210** and can be based on the first predetermined semantic cost and the salience of fourth word "have" **114**. A detailed description for determining the semantic similarity between two words (e.g., "got" and "have") in a semantic space is provided below.

Further, a second substitution cost associated with substituting the word "good" **116** of first text phrase **102** with the word "interesting" **118** is determined in response to determining that editing first text phrase **102** to match second text phrase **104** requires substituting the word "good" **116** of first text phrase **102** with the word "interesting" **118**. The second substitution cost can be determined in a similar or identical manner as the first substitution cost. For example, the second substitution cost:

$$cost_{sub}(\text{"good", "interesting"})=(cost_{del}(\text{"got"})+cost_{ins}(\text{"have"}))(1-\text{similarity}(\text{"got", "have"}))$$

It should be recognized that various modifications can be made for determining the insertion cost, the deletion cost, and the substitution cost. For example, various weighting factors can be included to adjust the relative cost associated with inserting, deleting, and substituting.

At block **216** of process **200**, a semantic edit distance between first text phrase **102** and second text phrase **104** in a semantic space can be determined. The semantic edit distance can be determined based on one or more of the insertion cost, the deletion cost, and the substitution cost determined at blocks **210**, **212**, and **214**. For example, the semantic edit distance can be a linear combination of the insertion cost, the first deletion cost, the second deletion cost, the first substitution cost, and the second substitution cost. Appropriate weighting factors can be applied to the various costs in determining the semantic edit distance. Further, the semantic space can be the same semantic space used to determine the semantic similarity between two words, described below.

At block **218** of process **200**, a centroid distance between a centroid position of first text phrase **102** in the semantic space and a centroid position of second text phrase **104** in the semantic space can be determined. The semantic space can be the same semantic space used to determine semantic similarity between third word **112** and fourth word **114** at block **214**. The centroid position of a text phrase can be determined based on the semantic position of one or more words of the text phrase in the semantic space. Further, the centroid position of the text phrase can be determined based on a salience of one or more words of the text phrase. For example, the centroid position of first text phrase **102** can be determined based on a weighted semantic position of one or more words of first text phrase **102** in the semantic space where the semantic position of the one or more words of first text phrase **102** is weighted by a salience of the one or more words of first text phrase **102**. Additional details for determining centroid position of a text phrase are provided below.

At block **220** of process **200**, a degree of semantic similarity between first text phrase **102** and second text phrase **104** can be determined. In some examples, the degree of semantic similarity between first text phrase **102** and second text phrase **104** can be determined based on the semantic edit distance of block **216** and/or the centroid distance of block **218**. In one example, the degree of semantic similarity between first text phrase **102** and second text phrase **104** can be based on a linear combination of the semantic edit distance and the centroid distance. Various weighting factors can be applied to the linear combination of the semantic edit distance and the centroid distance.

At block **222** of process **200**, a first intent associated with first text phrase **102** can be determined based on the degree of semantic similarity. For example, blocks **204** through **220** can be repeated to determine the degree of semantic similarity between first text phrase **102** and a plurality of text phrases. The plurality of text phrases can include the second text phrase. Further, the plurality of text phrases can be associated with a plurality of predetermined intents. In one example, it can be determined at block **222** that first text phrase **102** is most semantically similar to second text phrase **104** among the plurality of text phrases. In particular, the degree of semantic similarity can be based on the semantic edit distance and it can be determined that second text phrase **104** is associated with the lowest semantic edit distance among the plurality of text phrase. In this example, the first intent can be determined to be similar or identical to the predetermined intent associated with second text phrase **104**. Specifically, the first intent can be determined to be similar or identical to the predetermined intent of requesting a story.

At block **224** of process **200**, one or more tasks associated with first text phrase **102** can be performed based on the first intent. For example, the tasks of searching for a story on the Internet or a database and displaying a retrieved story can be performed based on the first intent of requesting a story.

Although blocks **202** through **224** of process **200** are shown in a particular order in FIG. **2**, it should be appreciated that these blocks can be performed in any order. For instance, in some examples, block **218** can be performed prior to block **216**. In addition, although process **200** is described above with reference to blocks **202** through **224**, it should be appreciated that in some cases, process **200** can include additional blocks. For instance, in some examples, process **200** can include determining whether first text phrase **102** includes a fifth word that second text phrase **104** does not include and determining whether a predetermined list of keywords includes the fifth word. The predetermined list of keywords can include words that are highly salient and thus strongly influence the semantics of a given text phrase. For example, the predetermined list of keywords can include profane words. Accordingly, the degree of semantic similarity at block **220** can be based on whether first text phrase **102** includes a fifth word that second text phrase **104** does not include and whether a predetermined list of keywords includes the fifth word. For example, the degree of semantic similarity between first text phrase **102** and second text phrase **104** can be determined to be poor in response to determining that first text phrase **102** includes a profane word that second text phrase **104** does not include and a predetermined list of keywords includes the profane word.

Further, one or more blocks of process **200** can be optional and/or one or more blocks of process **200** can be combined. For instance, in some examples, block **218** of determining a centroid distance can be optional. In other examples, blocks **222** and **224** of determining a first intent and performing one or more tasks can be optional.

In some examples, blocks **204**, **206**, and **208** of process **200** can be combined. In these examples, it can be determined whether editing first text phrase **102** to match second text phrase **104** requires one or more of: a) inserting a first word into the first text phrase, b) deleting a second word from the first text phrase, and c) substituting a third word of the first text phrase with a fourth word. In other examples, blocks **210**, **212**, and **214** can be combined. In these examples, in response to determining that editing the first text phrase to match the second text phrase requires one or more of inserting the first word into the first text phrase, deleting the second word from the first text phrase, and substituting the third word of the first text phrase with the fourth word, one or more of an insertion cost, a deletion cost, and a substitution cost can be determined.

FIG. **3** illustrates process **300** for exemplar-based natural language processing according to various examples. Process **300** can be described with simultaneous reference to FIGS. **1** and **3**.

At block **302** of process **300**, first text phrase **102** can be received. Block **302** can be similar or identical to block **202** of process **200** described above.

At block **304** of process **300**, one or more word-level differences of first text phrase **102** with respect to second text phrase **104** can be determined. Determining the one or more word-level differences can include comparing the words of first text phrase **102** to the words of second text phrase **104**. Block **304** can be similar or identical to any combination of block **204**, **206**, and **208** of process **200**. The one or more word-level differences can include one or more of a first word-level difference, a second word-level difference, and a third word-level difference.

A first word-level difference can comprise second text phrase **104** including a first word **106** that does not correspond to any word of first text phrase **102**. For example, first word "do" **106** of second text phrase **104** does not correspond to any word of first text phrase **102**. Thus, the absence of first word "do" **106** in first text phrase **102** can be determined to be a first word-level difference. Determining a first word-level difference can be similar or identical to determined whether editing first text phrase **102** to match second text phrase **104** would require inserting first word **106** into first text phrase **102**, as described above in block **204** of process **200**.

A second word-level difference can comprise first text phrase **102** including a second word **108** that does not correspond to any word of second text phrase **104**. For example, second word "to" **108** of first text phrase **102** does not correspond to any word of second text phrase **104**. Similarly, the word "tell" **110** of first text phrase **102** does not correspond to any word of second text phrase **104**. Thus, second word "to" and/or the word "tell" of first text phrase **102** can be determined to be second word-level differences. Determining a second word-level difference can be similar or identical to determining whether editing first text phrase **102** to match second text phrase **104** would require deleting second word **108** and/or word **110** from first text phrase **102**, as described above in block **206** of process **200**.

A third word-level difference can comprise first text phrase **102** including third word **112** that is different from a corresponding fourth word **114** of second text phrase **104**. For example, third word "got" **112** of first text phrase **102** can be different from corresponding fourth word "have" **114** of second text phrase **104**. Similarly, the word "good" **116** of first text phrase **102** can be different from the corresponding word "interesting" **118** of second text phrase **104**. Thus, third word "got" and/or the word "good" of first text phrase **102** can be determined to be third word-level differences. Determining a second word-level difference can be similar or identical to determining whether editing first text phrase **102** to match second text phrase **104** would require substituting third word **112** with fourth word **114** and/or substituting word **116** with word **118**, as described above in block **208** of process **200**.

At block **306**, in response to determining that the one or more word-level differences include the first word-level difference, a first semantic cost associated with the first word-level difference can be determined. The first semantic cost can be based on a first predetermined semantic cost and the salience of the first word. The first semantic cost can be similar or identical to the insertion cost described above in block **210** of process **200** and can be determined in a similar or identical manner as the insertion cost.

At block **308** of process **300**, in response to determining that the one or more word-level differences include the second word-level difference, a second semantic cost associated with the second word-level difference can be determined. The second semantic cost can be based on a second predetermined semantic cost and the salience of the second word. The second semantic cost can be similar or identical to the deletion cost described above in block **212** of process **200** and can be determined in a similar or identical manner as the deletion cost.

At block **310** of process **300**, in response to determining that the one or more word-level differences include the third word-level difference, a third semantic cost associated with the third word-level difference can be determined. The third semantic cost can be based on the salience of the third word, the salience of the fourth word, the semantic similarity between the third word and the fourth word, a first predetermined semantic cost, and a second predetermined semantic cost. The third semantic cost can be similar or identical to the substitution cost described above in block **214** of process **200** and can be determined in a similar or identical manner as the substitution cost.

At block **312** of process **300**, a total semantic cost associated with the one or more word-level differences can be based on the first semantic cost, the second semantic cost, and the third semantic cost. The total semantic cost can be determined in a similar or identical manner as the semantic edit distance described above in block **216** of process **200**. For example, the total semantic cost can be equal to the linear combination of the first semantic cost, the second semantic cost, and the third semantic cost. As described above, the first semantic cost, the second semantic cost, and the third semantic cost can be based on one or more of a salience of the first word, a salience of the second word, a salience of the third word, a salience of the fourth word, and a semantic similarity between the third word and the fourth word in a semantic space.

At block **314** of process **300**, a centroid distance between a centroid position of first text phrase **102** in the semantic space and a centroid position of second text phrase **104** in the semantic space can be determined. Block **314** can be similar or identical to block **218** of process **200** described above.

At block **316** of process **300**, a degree of semantic similarity between first text phrase **102** and second text phrase **104** can be based on the total semantic cost and/or the centroid distance. For example, the degree of semantic similarity can be based on a linear combination of the total semantic cost and the centroid distance. Block **316** can be similar or identical to block **220** of process **200** described above.

At block **318** of process **300**, a first intent associated with first text phrase **102** can be determined based on the degree of semantic similarity. Block **318** can be similar or identical to block **222** of process **200** described above.

At block **320** of process **300**, one or more tasks associated with first text phrase **102** can be performed based on the first intent. Block **320** can be similar or identical to block **224** of process **200** described above.

Although blocks **302** through **320** of process **300** are shown in a particular order in FIG. **3**, it should be appreciated that these blocks can be performed in any order and that some blocks can be combined. Further, one or more blocks of process **200** can be optional and/or one or more additional blocks can be included.

In some examples, process **300** can further include determining whether first text phrase **102** includes a fifth word that second text phrase **104** does not include and determining whether a predetermined list of keywords includes the fifth word. The degree of semantic similarity between first text phrase **102** and second text phrase can be based on whether first text phrase **102** includes a fifth word that second text phrase **104** does not include and whether a predetermined list of keywords includes the fifth word.

FIG. **4** illustrates process **400** for exemplar-based natural language processing of speech according to various examples. Exemplar-based natural language processing can be particularly advantageous for processing speech input for user intent. This can be because of exemplar-based natural language processing is less sensitive to the word-level errors that can typically be associated with speech-to-text conversion.

At block **402** of process **400**, an input text phrase can be obtained from a received speech input. For example, the input text phrase can be obtained by performing speech-to-text conversion on the received speech input. Speech-to-text conversion can be performing using automatic speech recognition methods known in the art. The received speech input and the input text phrase can be in natural language form. The input text phrase can be similar or identical to first text phrase described above at block **302** of process **300**.

At block **404** of process **400**, it can be determining whether the input text phrase includes a sensitive word of a predetermined list of sensitive words. The sensitive word can be strongly associated with a particular intent. The salience of the sensitive word can thus be significant where a phrase that includes the sensitive word is likely associated with the particular intent. In some examples, the sensitive word is a profane word.

At block **406** of process **400**, a degree of semantic similarity between the input text phrase and one or more exemplar text phrases can be determined in response to determining that the input text phrase does not include a sensitive word of a predetermined list of sensitive words. The degree of semantic similarity between the input text phrase and an exemplar text phrase of the one or more exemplar text phrases can be determined in a similar or identical manner as determining a degree of semantic similarity between the first text phrase and the second text phrase at blocks **304** through **316** of process **300**, described above. Further, the exemplar text phrase can be similar or identical to the second text phrase at block **304** of process **300**.

At block **408** of process **400**, an exemplar text phrase that is most semantically similar to the input text phrase among the one or more exemplar text phrases can be identified based on the determined degree of semantic similarity between the input text phrase and the one or more exemplar text phrases. In a specific example, the degree of semantic similarity can be based on the total semantic cost. It can be determined that a first exemplar text phrase is associated with the lowest total semantic cost among those of the plurality of exemplar text phrases. Therefore, in such an example, the first exemplar text phrase can be identified as most semantically similar to the input text phrase among the one or more exemplar text phases.

At block **410** of process **400**, a user intent associated with the received speech input can be determined based on the degree of semantic similarity between the input text phrase and the one or more exemplar text phrases. Block **410** can be similar or identical to block **318** of process **300**.

In some examples, in response to determining at block **404** that the input text phrase includes a sensitive word of a predetermined list of sensitive words, a user intent associated with the received speech input can be determined based on a predetermined intent associated with the sensitive word. In particular, the user intent can be determined to be similar or identical to the predetermined intent associated with the sensitive word.

In other examples, in response to determining at block **404** that the input text phrase does not include a sensitive word of a predetermined list of sensitive words, a user intent associated with the received speech input can be determined based on a predetermined intent associated with the exemplar text phrase that is most semantically similar to the input text phrase at block **408**.

At block **412** of process **400**, one or more tasks associated with the received speech input can be determined based on the user intent. Block **412** can be similar or identical to block **320** of process **300**.

Although blocks **402** through **412** of process **400** are shown in a particular order in FIG. **4**, it should be appreciated that these blocks can be performed in any order and that some blocks can be combined. Further, one or more blocks of process **400** can be optional and/or one or more additional blocks can be included.

It should be recognized that the terms "first word," "second word," "third word," "fourth word," "fifth word" and the like described herein can, in some cases, refer to tokens that each represent a single word or a group of words that should be treated as a single unit. For instance, in one example, "first word" can be the single word "many". In another example, "first word" can be the group of words "a lot of."

The various processes for exemplar-based natural language processing described herein can be performed using a system implementing a client-server model, and more specifically, a system capable of implementing a virtual assistant (e.g., system **500**, described below). In other examples, the processes for exemplar-based natural language processing described herein can be performed using a stand-alone electronic device (e.g., user device **502**, described below).

2. Salience of a Word

The salience of a word can represent the influence the word has over a phrase. A highly salient word can greatly affect the semantics of a phrase. Thus, inserting, deleting, or substituting a highly salient word in a phrase can significantly change the meaning of the phrase. Conversely, a word with low salience does not greatly affect the semantics of a phrase. Thus inserting, deleting, or substituting a word with low salience in a phrase may not significantly change the meaning of the phrase.

The salience of a word can be determined based on the frequency of occurrence of the word in a corpus of text. For example, the salience of a word can be expressed by term frequency-inverse document frequency (tf-idf) or a variant thereof. In one example, a corpus of text can include multiple categories of text phrases that each includes a multiple text phrases. A category of text phrases can represent a particular context of text phrases or a particular topic of text phrases. For example, a category of text phrases can include text phrases associated with a particular intent. The salience of a word can be based on a proportion of the plurality of categories that include the word. This can be expressed as:

$$\text{salience}(w) = 1 - \frac{|\{c \in \text{categories} \mid w \in c\}|}{|\text{categories}|}$$

where salience(w) denotes a salience of a particular word, categories denotes the various categories in the corpus, c denotes a particular category in categories, and w denotes the word. In a specific example, if there are 100 categories in a corpus and a first word appears in 99 of the categories, the salience of the first word, salience(first word), can be equal to 1−(99/100)=0.01. Thus, words that appear in a large proportion of categories in the corpus can have low salience while words that appear in a small proportion of categories in the corpus can have high salience.

In other examples, the salience of a word can be determined based on a function representing the indexing power of a word. For example, the salience of a word can be determined based on the normalized entropy of the word in a corpus. In particular,

$$\text{salience}(w) = 1 - \frac{1}{\log N} \sum_{c \in categories} p(c \mid w) \log p(c \mid w)$$

where N is the number of categories and p(c|w) is the probability that a word w is part of a phrase for the particular category c as opposed to other categories.

In yet other examples, the salience of a word can be arbitrarily determined. For example, the salience of a word in a predetermined list of sensitive words can be assigned an arbitrary value. In a specific example, a predetermined list of sensitive words can include a profane word and the salience of the profane word can be arbitrarily assigned a high salience.

3. Semantic Space, Semantic Similar, and Centroid Distance

The semantic similarity between two words (e.g., between third word **112** and fourth word **114**, described above in block **208**) can be determined using a semantic space. The semantic space can be an n-dimensional semantic space that is based on distributional semantics. Each word can be represented by a semantic position in the semantic space. The semantic position of a word can be expressed as a vector $\vec{v}_w$. The semantics of words can be compared based on the semantic distance between their vectors. For example, the semantic distance between the vector of a third word and the vector of a fourth word can represent the semantic similarity between the third word and the fourth word in the semantic space. In some examples, the semantic similarity between the third word and the fourth word in a semantic space can refer to the semantic distance between the vector of the third word and the vector of the fourth word in the semantic space. The semantic distance between vectors can be determined by taking an inner product of the semantic vectors. For example, the semantic distance (e.g., semantic similarity) between word w_1 and word w_2 can be determined as follows:

$$\text{similarity}_{word}(w_1, w_2) = \vec{v}_{w1} \cdot \vec{v}_{w2}$$

where $\vec{v}_{w1}$ denotes the vector representing word w_1 in the semantic space and $\vec{v}_{w2}$ denotes the vector representing word w_2 in the semantic space.

FIG. **5** illustrates semantic space **500** according to various examples. A plurality of points **502** are disposed in semantic space **500**. Each point represents a semantic position of a word in semantic space **500**. Words associated with points that are closer together in semantic space **500** are more semantically similar. Conversely, words associated with points that are further apart from each other are less semantically similar. For example, the semantic distance between the words “find” and “search” is less than the semantic distance between the words “find” and “shout.” Accordingly, the word “find” is more semantically similar to the word “search” than to the word “shout.”

Semantic space **500** can be derived from the distributions of words (e.g., a corpus) in a large body of unannotated text. In some examples, semantic space **500** can be derived from a corpus that includes a plurality of text phrases where each text phrase of the plurality of text phrases includes less than 150 characters. By using shorter text phrases to derive semantic space **500**, semantic space **500** can be more suitable for virtual assistant applications where input texts can typically be short questions, requests, or statements that can be less than 150 characters.

A semantic space can also be used to determine the semantic similarity between text phrases. For example, the semantic similarity between a first text phrase and a second text phrase can be represented by a centroid distance in a semantic space. The centroid distance can be the distance between a centroid position of the first text phrase in the semantic space and a centroid position of the second text phrase in the semantic space. The centroid position of a text phrase can represent the semantics of the text phrase in the semantic space. The centroid position of a text phrase can be expressed as a vector $\vec{r}(s)$ in the semantic space. For example, FIG. **6** illustrates centroid position **602** of text phrase **604** in semantic space **600** according to various examples. Semantic space **600** can be similar or identical to semantic space **500**. Centroid position **602** of text phrase **604** can be determined based on a semantic position of one or more words of text phrase **602** in the semantic space.

As shown in FIG. **6**, each word of text phrase **602** can be represented by a semantic position. For example, the word “stories” can be represented by semantic position **606**. In some examples, centroid position **602** can be determined by combining the vectors $\vec{v}_w$ of the words in text phrase **604**. Further, in some examples, centroid position **602** of text phrase **604** can be determined based on a salience of one or more words of text phrase **604**. For example, the vector $\vec{v}_w$ of each word of text phrase **604** can be weighted by the salience of the word and the weighted vectors salience(w)·$\vec{v}_w$ can be combined to determine centroid position **602**. In particular,

$$\vec{r}(s) = \sum_{w \in s} \text{salience}(w) \cdot \vec{v}_w$$

where $\vec{r}(s)$ denotes centroid position **602** of text phrase **604**, salience(w) denotes the salience of a word of text phrase **604**, $\vec{v}_w$ the semantic position of a word of text phrase **604**, s denotes text phrase **604**, and w denotes a word of text phrase **604**.

In some examples, the centroid distance between a centroid position of a first text phrase in the semantic space and a centroid position of a second text phrase in the semantic space can be determined by L^2 normalizing the centroid position of the first text phrase and the centroid position of the second text phrase. For example:

$$similarity_{centroid}(s_1, s_2) = \frac{\vec{r}(s_1) \cdot \vec{r}(s_2)}{\|\vec{r}(s_1)\| \|\vec{r}(s_2)\|}$$

where similarity$_{centroid}$(s_1, s_2) denotes the centroid distance between the centroid position $\vec{r}(s_1)$ of the first text phase s_1 and the centroid position $\vec{r}(s_2)$ of the second text phrase s_2.

4. System and Environment

FIG. **7** illustrates system **700** for carrying out various aspects of exemplar-based natural language processing according to various examples. In some examples, system **700** can implement a virtual assistant. The terms "virtual assistant," "digital assistant," "intelligent automated assistant," or "automatic digital assistant," can refer to any information processing system (e.g., system **700**) that can interpret natural language input in spoken and/or textual form to infer user intent, and perform actions based on the inferred user intent.

The virtual assistant can be capable of processing natural language input. For example, virtual assistant can be capable of performing speech recognition on a spoken input in order to obtain a textual representation of the spoken input. The textual representation can be analyzed to infer user intent. The virtual assistant can then act on the inferred user intent by performing one or more of the following: identifying a task flow with steps and parameters designed to accomplish the inferred user intent; inputting specific requirements from the inferred user intent into the task flow; executing the task flow by invoking programs, methods, services, APIs, or the like; and generating output responses to the user in an audible (e.g., speech) and/or visual form.

An example of a virtual assistant is described in Applicants' U.S. Utility application Ser. No. 12/987,982 for "Intelligent Automated Assistant," filed Jan. 10, 2011, the entire disclosure of which is incorporated herein by reference

As shown in FIG. **7**, in some examples, a virtual assistant can be implemented according to a client-server model. The virtual assistant can include a client-side portion executed on user device **702**, and a server-side portion executed on server system **710**. User device **702** can include any electronic device, such as a mobile phone, tablet computer, portable media player, desktop computer, laptop computer, PDA, television, television set-top box, wearable electronic device, or the like, and can communicate with server system **710** through one or more networks **708**, which can include the Internet, an intranet, or any other wired or wireless public or private network. A detailed description of user device **702** is provided below with reference to FIG. **8**. The client-side portion executed on user device **702** can provide client-side functionalities, such as user-facing input and output processing and communications with server system **710**. Server system **710** can provide server-side functionalities for any number of clients residing on a respective user device **702**.

Server system **710** can include one or more virtual assistant servers **714**. As shown in FIG. **7**, virtual assistant server **714** includes memory **728**, one or more processors **726**, client-facing I/O interface **722**, and I/O interface to external services **716**. The various components of virtual assistant server **714** can be coupled together by one or more communication buses or signal lines. Memory **728**, or the computer-readable storage media of memory **728**, can include one or more processing modules **718** and data and model storage **720**. The one or more processing modules **718** can include various programs and instructions. The one or more processors **726** can execute the programs and instructions of the one or more processing modules **728** and read/write to/from data and model storage **720**. In the context of this document, a "non-transitory computer-readable storage medium" can be any medium that can contain or store the program for use by or in connection with the instruction execution system, apparatus, or device.

In some examples, the one or more processing modules **718** can include various programs and instructions for performing various aspects of exemplar-based natural language processing (e.g., processes **200**, **300**, or **400**, described above). In some examples, the one or more processing modules **718** can include a speech-to-text processing module, a natural language processing module, a task flow processing module, and a service processing module. The speech-to-text processing module can include instructions for transcribing a speech utterance in an audio input. The natural language processing module can include instructions for inferring user intent from the transcribed speech utterance. For example, the natural language processing model can include various instructions for exemplar-based natural language processing (e.g., processes **200**, **300**, or **400**). The task flow processing module and the service processing module can include instructions for identifying a task flow to accomplish the inferred user intent, inputting specific requirements from the inferred user intent into the task flow, executing the task flow, and outputting relevant responses to the speech utterance. For example, the task flow processing module and the service processing module can include instructions for performing one or more task associated with the natural language input (e.g., blocks **224**, **320**, and **412**, described above). Data and models **720** can include various user data and models that can be accessed or referenced when performing various aspects of exemplar-based natural language processing. For example, data and models **720** can include speech models, language models, task flow models, and service models.

In some examples, virtual assistant server **714** can communicate with external services **724**, such as telephony services, calendar services, information services, messaging services, navigation services, and the like, through network(s) **708** for task completion or information acquisition. The I/O interface to external services **716** can facilitate such communications.

Server system **710** can be implemented on one or more standalone data processing devices or a distributed network of computers. In some examples, server system **710** can employ various virtual devices and/or services of third-party service providers (e.g., third-party cloud service providers) to provide the underlying computing resources and/or infrastructure resources of server system **710**.

Although the functionality of the virtual assistant is shown in FIG. **7** as including both a client-side portion and a server-side portion, in some examples, the functions of the assistant can be implemented as a standalone application installed on a user device (e.g., user device **702**). In addition, the division of functionalities between the client and server portions of the virtual assistant can vary in different examples. For instance, in some examples, one or more processing modules **718** and data and models **720** can be stored in the memory of user device **702** to enable user device to perform a greater proportion or all of the functionalities associated with the virtual assistant. In other examples, the client executed on user device **702** can be a thin-client that provides only user-facing input and output processing functions, and delegates all other functionalities of the virtual assistant to a backend server.

5. User Device

FIG. **8** is a block diagram of a user-device **702** according to various examples. As shown, user device **702** can include a memory interface **802**, one or more processors **804**, and a peripherals interface **806**. The various components in user device **702** can be together coupled by one or more communication buses or signal lines. User device **702** can further include various sensors, subsystems, and peripheral devices that are coupled to the peripherals interface **806**. The sensors, subsystems, and peripheral devices gather information and/or facilitate various functionalities of user device **702**.

For example, user device **702** can include a motion sensor **810**, a light sensor **812**, and a proximity sensor **814** coupled to peripherals interface **806** to facilitate orientation, light, and proximity sensing functions. One or more other sensors **816**, such as a positioning system (e.g., a GPS receiver), a temperature sensor, a biometric sensor, a gyroscope, a compass, an accelerometer, and the like, are also connected to peripherals interface **806**, to facilitate related functionalities.

In some examples, a camera subsystem **820** and an optical sensor **822** can be utilized to facilitate camera functions, such as taking photographs and recording video clips. Communication functions can be facilitated through one or more wired and/or wireless communication subsystems **824**, which can include various communication ports, radio frequency receivers and transmitters, and/or optical (e.g., infrared) receivers and transmitters. An audio subsystem **826** can be coupled to speakers **828** and a microphone **830** to facilitate audio-enabled functions, such as voice recognition, music recognition, voice replication, digital recording, and telephony functions. For example, user-device **702** can receive speech input (e.g., received speech input at block **402**) via microphone **830**.

In some examples, user device **702** can further include an I/O subsystem **840** coupled to peripherals interface **806**. I/O subsystem **840** can include a touch screen controller **842** and/or other input controller(s) **844**. Touch-screen controller **842** can be coupled to a touch screen **846**. Touch screen **846** and the touch screen controller **842** can, for example, detect contact and movement or break thereof using any of a plurality of touch sensitivity technologies, such as capacitive, resistive, infrared, surface acoustic wave technologies, proximity sensor arrays, and the like. Other input controller(s) **844** can be coupled to other input/control devices **848**, such as one or more buttons, rocker switches, keyboard, a thumb-wheel, an infrared port, a USB port, and/or a pointer device such as a stylus. In some examples, text input (e.g., block **202** and **302**) can be received via a text inputting interface displayed on touch screen **846** or other input/control devices **848**.

In some examples, user device **702** can further include a memory interface **802** coupled to memory **850**. Memory **850** can include any electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, a portable computer diskette (magnetic), a random access memory (RAM) (magnetic), a read-only memory (ROM) (magnetic), an erasable programmable read-only memory (EPROM) (magnetic), a portable optical disc such as CD, CD-R, CD-RW, DVD, DVD-R, or DVD-RW, or flash memory such as compact flash cards, secured digital cards, USB memory devices, memory sticks, and the like. In some examples, a non-transitory computer-readable storage medium of memory **850** can be used to store instructions (e.g., for performing processes **200**, **300**, or **400**, described above) for use by or in connection with an instruction execution system, apparatus, or device, such as a computer-based system, processor-containing system, or other system that can fetch the instructions from the instruction execution system, apparatus, or device and execute the instructions. In other examples, the instructions (e.g., for performing process **200**, **300**, or **400**, described above) can be stored on a non-transitory computer-readable storage medium of server system **710**, or can be divided between the non-transitory computer-readable storage medium of memory **850** and the non-transitory computer-readable storage medium of server system **710**.

In some examples, the memory **850** can store an operating system **852**, a communication module **854**, a graphical user interface module **856**, a sensor processing module **858**, a phone module **860**, and applications **862**. Operating system **852** can include instructions for handling basic system services and for performing hardware dependent tasks. Communication module **854** can facilitate communicating with one or more additional devices, one or more computers and/or one or more servers. Graphical user interface module **856** can facilitate graphic user interface processing. Sensor processing module **858** can facilitate sensor related processing and functions. Phone module **860** can facilitate phone-related processes and functions. Application module **862** can facilitate various functionalities of user applications, such as electronic-messaging, web browsing, media processing, navigation, imaging and/or other processes and functions.

As described herein, memory **850** can also store client-side virtual assistant instructions (e.g., in a virtual assistant client module **864**) and various user data and models **866** to provide the client-side functionalities of the virtual assistant. The virtual assistant client module **864** can include modules, instructions, and programs for performing various aspects of processes **200**, **300**, or **400** described above. In some cases, the instructions for performing various aspects of process **100** can be stored in a separate module in memory **850**. User data and models **866** can include user-specific vocabulary data, preference data, and/or other data such as the user's electronic address book, to-do lists, shopping lists, and the like. In addition, user data and models **866** can include speech models, language models, task flow models, and service models.

In various examples, virtual assistant client module **864** can include instructions for accepting natural language input (e.g., speech and/or text), touch input, and/or gestural input through various user interfaces (e.g., I/O subsystem **840**, audio subsystem **826**, or the like) of user device **702**. Virtual assistant client module **864** can also include instructions for providing output in audio (e.g., speech and/or music output), visual, and/or tactile forms. For example, output can be provided as voice, music, sound, alerts, text messages, menus, graphics, videos, animations, vibrations, and/or combinations of two or more of the above. During operation, user device **702** can communicate with the virtual assistant server using communication subsystems **824** to perform the functionalities associated with the virtual assistant.

In various examples, memory **850** can include additional instructions or fewer instructions. Furthermore, various functions of user device **702** can be implemented in hardware and/or in firmware, including in one or more signal processing and/or application specific integrated circuits.

6. Electronic Device

FIG. **9** shows a functional block diagram of an electronic device **900** configured in accordance with the principles of the various described examples. The functional blocks of the device can be, optionally, implemented by hardware, software, or a combination of hardware and software to carry out the principles of the various described examples. It is understood by persons of skill in the art that the functional blocks described in FIG. **9** can be, optionally, combined, or separated into sub-blocks to implement the principles of the various described examples. Therefore, the description herein optionally supports any possible combination, separation, or further definition of the functional blocks described herein.

As shown in FIG. **9**, electronic device **900** can include touch screen display unit **902** configured to display a user interface and to receive touch input, and audio receiving unit **904** configured to receive speech input. In some examples, electronic device **900** can include speaker unit **906** configured to generate sound and text receiving unit **908** configured to receive text. Electronic device **900** can further include processing unit **910** coupled to touch screen display unit **902** and audio receiving unit **904** (and, optionally, coupled to speaker unit **906** and text input receiving unit **908**). In some examples, processing unit **910** can include receiving unit **912**, determining unit **914**, and performing unit **916**.

Processing unit **910** can be configured to receive a first text phrase (e.g., from text receiving unit **908** or touch screen display unit **902** and using receiving unit **912**). Processing unit **910** can be configured to determine (e.g., using determining unit **914**) whether editing the first text phrase to match a second text phrase requires one or more of inserting a first word into the first text phrase, deleting a second word from the first text phrase, and substituting a third word of the first text phrase with a fourth word. The second text phrase includes the first word, the first text phrase includes the second word, and the second text phrase includes the fourth word. Processing unit **910** can be configured to determine (e.g., using determining unit **914**) one or more of an insertion cost, a deletion cost, and a substitution cost in response to determining that editing the first text phrase to match the second text phrase requires one or more of inserting the first word into the first text phrase, deleting the second word from the first text phrase, and substituting the third word of the first text phrase with the fourth word. The insertion cost is associated with inserting the first word into the first text phrase, the deletion cost is associated with deleting the second word from the first text phrase, and the substitution cost is associated with substituting the third word of the first text phrase with the fourth word. Processing unit **910** can be configured to determine (e.g., using determining unit **914**), based on the one or more of the insertion cost, the deletion cost, and the substitution cost, a semantic edit distance between the first text phrase and the second text phrase in a semantic space. A degree of semantic similarity between the first text phrase and the second text phrase is based on the semantic edit distance.

In some examples, processing unit **910** can be configured to determine (e.g., using determining unit **914**), based on the degree of semantic similarity between the first text phrase and the second text phrase, a first intent associated with the first text phrase. In some examples, processing unit **910** can be configured to perform (e.g., using performing unit **914**), based on the first intent, a task associated with the first text phrase.

In some examples, processing unit **910** can be configured to determine (e.g., using determining unit **914**) the insertion cost associated with inserting the first word into the first text phrase in response to determining that editing the first text phrase to match the second text phrase requires inserting the first word into the first text phrase. The insertion cost is determined based on a first predetermined semantic cost and a salience of the first word.

In some examples, processing unit **910** can be configured to determine (e.g., using determining unit **914**) the deletion cost associated with deleting the second word from the first text phrase in response to determining that editing the first text phrase to match the second text phrase requires deleting the second word from the first text phrase. The deletion cost is determined based on a second predetermined semantic cost and a salience of the second word.

In some examples, processing unit **910** can be configured to determine (e.g., using determining unit **914**) the substitution cost associated with substituting the third word of the first text phrase with the fourth word in response to determining that editing the first text phrase to match the second text phrase requires substituting the third word of the first text phrase with the fourth word. The substitution cost is determined based on a salience of the third word, a salience of the fourth word, a semantic similarity between the third word and the fourth word in the semantic space, a first predetermined semantic cost, and a second predetermined semantic cost.

In some examples, the first predetermined semantic cost is higher than the second predetermined semantic cost.

In some examples, the salience of the first word is based on a frequency of occurrence of the first word in a first corpus. In some examples, the salience of the second word is based on a frequency of occurrence of the second word in the first corpus. In some examples, the salience of the third word is based on a frequency of occurrence of the third word in the first corpus. In some examples, the salience of the fourth word is based on a frequency of occurrence of the fourth word in the first corpus.

In some examples, the first corpus comprises a plurality of categories that includes a plurality of text phrases. The salience of the first word is based on a proportion of the plurality of categories that include the first word. The salience of the second word is based on a proportion of the plurality of categories that include the second word. The salience of the third word is based on a proportion of the plurality of categories that include the third word. The salience of the fourth word is based on a proportion of the plurality of categories that include the fourth word.

In some examples, the salience of the first word is based on a normalized entropy of the first word in a second corpus. The salience of the second word is based on a normalized entropy of the second word in the second corpus. The salience of the third word is based on a normalized entropy of the third word in the second corpus. The salience of the fourth word is based on a normalized entropy of the fourth word in the second corpus.

In some examples, the salience of the first word is based on whether a first predetermined list of sensitive words includes the first word. The salience of the second word is based on whether a second predetermined list of sensitive words includes the second word. The salience of the third word is based on whether a third predetermined list of sensitive words includes the third word. The salience of the fourth word is based on whether a fourth predetermined list of sensitive words includes the fourth word.

In some examples, processing unit **910** can be configured to determine (e.g., using determining unit **914**) a centroid distance between a centroid position of the first text phrase in the semantic space and a centroid position of the second text phrase in the semantic space. The degree of semantic similarity between the first text phrase and the second text phrase is based on the centroid distance.

In some example, the centroid position of the first text phrase is determined based on a semantic position of one or more words of the first text phrase in the semantic space and the centroid position of the second text phrase is determined based on a semantic position of one or more words of the second text phrase in the semantic space.

In some examples, the centroid position of the first text phrase is determined based on a salience of one or more words of the first text phrase and the centroid position of the second text phrase is determined based on a salience of one or more words of the second text phrase.

In some examples, the degree of semantic similarity is based on a linear combination of the semantic edit distance and the centroid distance.

In some examples, the degree of semantic similarity is based on whether the first text phrase includes a fifth word that the second text phrase does not include and whether a predetermined list of keywords includes the fifth word.

In some examples, the semantic space is derived from a second corpus that includes a plurality of text phrases, and wherein each text phrase of the plurality of text phrases includes less than 150 characters.

FIG. **10** shows a functional block diagram of an electronic device **900** configured in accordance with the principles of the various described examples. The functional blocks of the device can be, optionally, implemented by hardware, software, or a combination of hardware and software to carry out the principles of the various described examples. It is understood by persons of skill in the art that the functional blocks described in FIG. **10** can be, optionally, combined, or separated into sub-blocks to implement the principles of the various described examples. Therefore, the description herein optionally supports any possible combination, separation, or further definition of the functional blocks described herein.

As shown in FIG. **10**, electronic device **1000** can include touch screen display unit **1002** configured to display a user interface and to receive touch input, and audio receiving unit **1004** configured to receive speech input. In some examples, electronic device **1000** can include speaker unit **1006** configured to generate sound and text receiving unit **1008** configured to receive text. Electronic device **1000** can further include processing unit **1010** coupled to touch screen display unit **1002** and audio receiving unit **1004** (and, optionally, coupled to speaker unit **1006** and text input receiving unit **1008**). In some examples, processing unit **1010** can include receiving unit **1012**, determining unit **1014**, and performing unit **1016**.

Processing unit **1010** can be configured to receive a first text phrase (e.g., from text receiving unit **1008** or touch screen display unit **1002** and using receiving unit **1012**). Processing unit **1010** can be configured to determine (e.g., using determining unit **1014**) one or more word-level differences of the first text phrase with respect to a second text phrase. The one or more word-level differences can include one or more of a first word-level difference comprising the second text phrase including a first word that does not correspond to any word of the first text phrase, a second word-level difference comprising the first text phrase including a second word that does not correspond to any word of the second text phrase, and a third word-level difference comprising the first text phrase including a third word that is different from a corresponding fourth word of the second text phrase. Processing unit **1010** can be configured to determine (e.g., using determining unit **1014**) a total semantic cost associated with the one or more word-level differences based on one or more of a salience of the first word, a salience of the second word, a salience of the third word, a salience of the fourth word, and a semantic similarity between the third word and the fourth word in a semantic space. A degree of semantic similarity between the first text phrase and the second text phrase is based on the total semantic cost.

In some examples, processing unit **1010** can be configured to determine (e.g., using determining unit **1014**), based on the degree of semantic similarity between the first text phrase and the second text phrase, a first intent associated with the first text phrase. In some examples, processing unit **1010** can be configured to perform (e.g., using performing unit **1016**), based on the first intent, a task associated with the first text phrase.

In some examples, processing unit **1010** can be configured to determine (e.g., using determining unit **1014**), in response to determining that the one or more word-level differences include the first word-level difference, a first semantic cost associated with the first word-level difference based on a first predetermined semantic cost and the salience of the first word. The total semantic cost includes the first semantic cost.

In some examples, processing unit **1010** can be configured to determine (e.g., using determining unit **1014**), in response to determining that the one or more word-level differences include the second word-level difference, a second semantic cost associated with the second word-level difference based on a second predetermined semantic cost and the salience of the second word. The total semantic cost includes the second semantic cost.

In some examples, the first predetermined semantic cost is higher than the second predetermined semantic cost.

In some examples, processing unit **1010** can be configured to determine (e.g., using determining unit **1014**), in response to determining that the one or more word-level differences include the third word-level difference, a third semantic cost associated with the third word-level difference based on the salience of the third word, the salience of the fourth word, the semantic similarity between the third word and the fourth word, a first predetermined semantic cost, and a second predetermined semantic cost. The total semantic cost includes the third semantic cost.

In some examples, the salience of the first word is based on a frequency of occurrence of the first word in a first corpus. The salience of the second word is based on a frequency of occurrence of the second word in the first corpus. The salience of the third word is based on a frequency of occurrence of the third word in the first corpus. The salience of the fourth word is based on a frequency of occurrence of the fourth word in the first corpus.

In some examples, the first corpus comprises a plurality of categories that includes a plurality of text phrases. The salience of the first word is based on a proportion of the plurality of categories that include the first word. The salience of the second word is based on a proportion of the plurality of categories that include the second word. The salience of the third word is based on a proportion of the plurality of categories that include the third word. The salience of the fourth word is based on a proportion of the plurality of categories that include the fourth word.

In some examples, the salience of the first word is based on a normalized entropy of the first word in a second corpus. The salience of the second word is based on a normalized entropy of the second word in the second corpus. The salience of the third word is based on a normalized entropy of the third word in the second corpus. The salience of the fourth word is based on a normalized entropy of the fourth word in the second corpus.

In some examples, the salience of the first word is based on whether a first predetermined list of sensitive words includes the first word. The salience of the second word is based on whether a second predetermined list of sensitive words includes the second word. The salience of the third word is based on whether a third predetermined list of sensitive words includes the third word. The salience of the fourth word is based on whether a fourth predetermined list of sensitive words includes the fourth word.

In some examples, processing unit **1010** can be configured to determine (e.g., using determining unit **1014**) a centroid distance between a centroid position of the first text phrase in the semantic space and a centroid position of the second text phrase in the semantic space. The degree of semantic similarity between the first text phrase and the second text phrase is based on the centroid distance.

In some examples, the centroid position of the first text phrase is determined based on a semantic position of one or more words of the first text phrase in the semantic space and the centroid position of the second text phrase is determined based on a semantic position of one or more words of the second text phrase in the semantic space.

In some examples, the centroid position of the first text phrase is determined based on a salience of one or more words of the first text phrase and the centroid position of the second text phrase is determined based on a salience of one or more words of the second text phrase.

In some examples, the degree of semantic similarity is based on a linear combination of the total semantic cost and the centroid distance.

In some examples, the degree of semantic similarity between the first text phrase and the second text phrase is based on whether the first text phrase includes a fifth word that the second text phrase does not include and whether a predetermined list of keywords includes the fifth word.

In some examples, the semantic space is derived from a third corpus that includes a plurality of text phrases, and wherein each text phrase of the plurality of text phrases includes less than 150 characters.

FIG. **11** shows a functional block diagram of an electronic device **900** configured in accordance with the principles of the various described examples. The functional blocks of the device can be, optionally, implemented by hardware, software, or a combination of hardware and software to carry out the principles of the various described examples. It is understood by persons of skill in the art that the functional blocks described in FIG. **11** can be, optionally, combined, or separated into sub-blocks to implement the principles of the various described examples. Therefore, the description herein optionally supports any possible combination, separation, or further definition of the functional blocks described herein.

As shown in FIG. **11**, electronic device **1100** can include touch screen display unit **1102** configured to display a user interface and to receive touch input, and audio receiving unit **1104** configured to receive speech input. In some examples, electronic device **1100** can include speaker unit **1106** configured to generate sound and text receiving unit **1108** configured to receive text. Electronic device **1100** can further include processing unit **1110** coupled to touch screen display unit **1102** and audio receiving unit **1104** (and, optionally, coupled to speaker unit **1106** and text input receiving unit **1108**). In some examples, processing unit **1110** can include receiving unit **1112**, determining unit **1114**, performing unit **1116**, and identifying unit **1118**.

Processing unit **1110** can be configured to obtain an input text phrase from a received speech input (e.g., from audio receiving unit **1104** and using obtaining unit **1112**). Processing unit **1110** can be configured to determine (e.g., using determining unit **1114**) a degree of semantic similarity between the input text phrase and one or more exemplar text phrases. Determining a degree of semantic similarity between the input text phrase and an exemplar text phrase of the one or more exemplar text phrases can comprises determining one or more word-level differences of the input text phrase with respect to the exemplar text phrase. Processing unit **1110** can be configured to determine (e.g., using determining unit **1114**) one or more word-level differences of the input text phrase with respect to the exemplar text phrase. The one or more word-level differences include one or more of a first word-level difference comprising the exemplar text phrase including a first word that does not correspond to any word of the input text phrase, a second word-level difference comprising the input text phrase including a second word that does not correspond to any word of the exemplar text phrase, and a third word-level difference comprising the input text phrase including a third word that is different from a corresponding fourth word of the exemplar text phrase. Processing unit **1110** can be configured to determine (e.g., using determining unit **1114**) a total semantic cost associated with the one or more word-level differences based on one or more of a salience of the first word, a salience of the second word, a salience of the third word, a salience of the fourth word, and a semantic similarity between the third word and the fourth word in a semantic space. A degree of semantic similarity between the input text phrase and the exemplar text phrase is based on the total semantic cost.

In some examples, processing unit **1110** can be configured to determine (e.g., using determining unit **1114**), based on the degree of semantic similarity between the input text phrase and the exemplar text phrase, a user intent associated with the received speech input. In some examples, processing unit **1110** can be configured to perform (e.g., using performing unit **1116**), based on the user intent, a task associated with the received speech input.

In some examples, processing unit **1110** can be configured to identify (e.g., using identifying unit **1118**), based on the determined degree of semantic similarity, an exemplar text phrase that is most semantically similar to the input text phrase among the one or more exemplar text phrases. In some examples, processing unit **1110** can be configured to determine (e.g., using determining unit **1114**) a user intent associated with the received speech input based on a predetermined intent associated with the exemplar text phrase that is most semantically similar to the input text phrase.

In some examples, processing unit **1110** can be configured to determine (e.g., using determining unit **1114**) whether the input text phrase includes a sensitive word of a predetermined list of sensitive words. In some examples, processing unit **1110** can be configured to determine (e.g., using determining unit **1114**), in response to determining that the input text phrase includes a sensitive word of a predetermined list of sensitive words, a user intent associated with the received speech input based on a predetermined intent associated with the sensitive word. In some examples, the degree of semantic similarity between the input text phrase and the one or more exemplar text phrases is determined in response to determining that the input text phrase does not include a sensitive word of a predetermined list of sensitive words.

In some examples, processing unit **1110** can be configured to determine (e.g., using determining unit **1114**), in response to determining that the one or more word-level differences include the first word-level difference, a first semantic cost associated with the first word-level difference based on a first predetermined semantic cost and the salience of the first word. The total semantic cost can include the first semantic cost.

In some examples, processing unit **1110** can be configured to determine (e.g., using determining unit **1114**), in response to determining that the one or more word-level differences include the second word-level difference, determining a second semantic cost associated with the second word-level difference based on a second predetermined semantic cost and the salience of the second word. The total semantic cost can include the second semantic cost.

In some examples, the first predetermined semantic cost is higher than the second predetermined semantic cost.

In some examples, processing unit **1110** can be configured to determine (e.g., using determining unit **1114**), in response to determining that the one or more word-level differences include the third word-level difference, a third semantic cost associated with the third word-level difference based on the salience of the third word, the salience of the fourth word, the semantic similarity between the third word and the fourth word, a first predetermined semantic cost, and a second predetermined semantic cost. The total semantic cost can include the third semantic cost.

In some examples, the salience of the first word is based on a frequency of occurrence of the first word in a first corpus. The salience of the second word is based on a frequency of occurrence of the second word in the first corpus. The salience of the third word is based on a frequency of occurrence of the third word in the first corpus. The salience of the fourth word is based on a frequency of occurrence of the fourth word in the first corpus.

In some examples, the first corpus comprises a plurality of categories that includes a plurality of text phrases. The salience of the first word is based on a proportion of the plurality of categories that include the first word. The salience of the second word is based on a proportion of the plurality of categories that include the second word. The salience of the third word is based on a proportion of the plurality of categories that include the third word. The salience of the fourth word is based on a proportion of the plurality of categories that include the fourth word.

In some examples, the salience of the first word is based on a normalized entropy of the first word in a second corpus. The salience of the second word is based on a normalized entropy of the second word in the second corpus. The salience of the third word is based on a normalized entropy of the third word in the second corpus. The salience of the fourth word is based on a normalized entropy of the fourth word in the second corpus.

In some examples, the salience of the first word is based on whether a first predetermined list of sensitive words includes the first word. The salience of the second word is based on whether a second predetermined list of sensitive words includes the second word. The salience of the third word is based on whether a third predetermined list of sensitive words includes the third word. The salience of the fourth word is based on whether a fourth predetermined list of sensitive words includes the fourth word.

In some examples, processing unit **1110** can be configured to determine (e.g., using determining unit **1114**), a centroid distance between a centroid position of the input text phrase in the semantic space and a centroid position of the exemplar text phrase in the semantic space. The degree of semantic similarity between the input text phrase and the exemplar text phrase is based on the centroid distance.

In some examples, the centroid position of the input text phrase is determined based on a semantic position of one or more words of the input text phrase in the semantic space and the centroid position of the exemplar text phrase is determined based on a semantic position of one or more words of the exemplar text phrase in the semantic space.

In some examples, the centroid position of the input text phrase is determined based on a salience of one or more words of the input text phrase and the centroid position of the exemplar text phrase is determined based on a salience of one or more words of the exemplar text phrase.

In some examples, the degree of semantic similarity is based on a linear combination of the total semantic cost and the centroid distance.

In some examples, the degree of semantic similarity between the input text phrase and the exemplar text phrase is based on whether the input text phrase includes a fifth word that the exemplar text phrase does not include and whether a predetermined list of keywords includes the fifth word.

In some examples, the semantic space is derived from a third corpus that includes a plurality of text phrases where each text phrase of the plurality of text phrases includes less than 150 characters.

Although examples have been fully described with reference to the accompanying drawings, it is to be noted that various changes and modifications will become apparent to those skilled in the art. Such changes and modifications are to be understood as being included within the scope of the various examples as defined by the appended claims.

In some cases, the systems, processes, and devices described above can include the gathering and use of data available from various sources to improve the delivery to users of invitational content or any other content that may be of interest to them. The present disclosure contemplates that in some instances, this gathered data may include personal information data that uniquely identifies or can be used to contact or locate a specific person. Such personal information data can include demographic data, location-based data, telephone numbers, email addresses, home addresses, or any other identifying information.

The present disclosure recognizes that the use of such personal information data in connection with the systems, processes, and devices described above, can be used to the benefit of users. For example, the personal information data can be used to deliver targeted content that is of greater interest to the user. Accordingly, use of such personal information data enables calculated control of the delivered content. Further, other uses for personal information data that benefit the user are also contemplated by the present disclosure.

The present disclosure further contemplates that the entities responsible for the collection, analysis, disclosure, transfer, storage, or other use of such personal information data will comply with well-established privacy policies and/or privacy practices. In particular, such entities should implement and consistently use privacy policies and practices that are generally recognized as meeting or exceeding industry or governmental requirements for maintaining personal information data private and secure. For example, personal information from users should be collected for legitimate and reasonable uses of the entity and not shared or sold outside of those legitimate uses. Further, such collection should occur only after receiving the informed consent of the users. Additionally, such entities would take any needed steps for safeguarding and securing access to such personal information data and ensuring that others with access to the personal information data adhere to their privacy policies and procedures. Further, such entities can subject themselves to evaluation by third parties to certify their adherence to widely accepted privacy policies and practices.

Despite the foregoing, the present disclosure also contemplates examples in which users selectively block the use of, or access to, personal information data. That is, the present disclosure contemplates that hardware and/or software elements can be provided to prevent or block access to such personal information data. For example, in the case of advertisement delivery services, the systems and devices described above can be configured to allow users to select to "opt in" or "opt out" of participation in the collection of personal information data during registration for services. In another example, users can select not to provide location information for targeted content delivery services. In yet another example, users can select to not provide precise location information, but permit the transfer of location zone information.

Therefore, although the present disclosure broadly covers use of personal information data to implement one or more various disclosed examples, the present disclosure also contemplates that the various examples can also be implemented without the need for accessing such personal information data. That is, the various examples disclosed herein are not rendered inoperable due to the lack of all or a portion of such personal information data. For example, content can be selected and delivered to users by inferring preferences based on non-personal information data or a bare minimum amount of personal information, such as the content being requested by the device associated with a user, other non-personal information available to the content delivery services, or publically available information.

What is claimed is:

1. A method for processing natural language comprising: at an electronic device:

receiving a first text phrase;

determining whether editing the first text phrase to match a second text phrase requires one or more of:

inserting a first word into the first text phrase, wherein the second text phrase includes the first word;

deleting a second word from the first text phrase; wherein the first text phrase includes the second word; and

substituting a third word of the first text phrase with a fourth word, wherein the second text phrase includes the fourth word;

in response to determining that editing the first text phrase to match the second text phrase requires one or more of inserting the first word into the first text phrase, deleting the second word from the first text phrase, and substituting the third word of the first text phrase with the fourth word, determining one or more of:

an insertion cost associated with inserting the first word into the first text phrase;

a deletion cost associated with deleting the second word from the first text phrase; and

a substitution cost associated with substituting the third word of the first text phrase with the fourth word;

determining, based on the one or more of the insertion cost, the deletion cost, and the substitution cost, a semantic edit distance between the first text phrase and the second text phrase in a semantic space, wherein a degree of semantic similarity between the first text phrase and the second text phrase is based on the semantic edit distance;

determining, based on the degree of semantic similarity between the first text phrase and the second text phrase, a first intent associated with the first text phrase; and

performing, based on the first intent, a task associated with the first text phrase.

2. The method according to claim **1**, wherein:

the insertion cost associated with inserting the first word into the first text phrase is determined in response to determining that editing the first text phrase to match the second text phrase requires inserting the first word into the first text phrase; and

the insertion cost is determined based on a first predetermined semantic cost and a salience of the first word.

3. The method according to claim **1**, wherein:

the deletion cost associated with deleting the second word from the first text phrase is determined in response to determining that editing the first text phrase to match the second text phrase requires deleting the second word from the first text phrase; and

the deletion cost is determined based on a second predetermined semantic cost and a salience of the second word.

4. The method according to claim **1**, wherein:

the substitution cost associated with substituting the third word of the first text phrase with the fourth word is determined in response to determining that editing the first text phrase to match the second text phrase requires substituting the third word of the first text phrase with the fourth word; and the substitution cost is determined based on a salience of the third word, a salience of the fourth word, a semantic similarity between the third word and the fourth word in the semantic space, a first predetermined semantic cost, and a second predetermined semantic cost.

5. The method according to claim **1**, wherein:

the insertion cost is determined based on a first predetermined semantic cost and a salience of the first word;

the deletion cost is determined based on a second predetermined semantic cost and a salience of the second word; and

the first predetermined semantic cost is higher than the second predetermined semantic cost.

6. The method according to claim **1**, wherein:

the insertion cost is determined based on a first predetermined semantic cost and a salience of the first word;

the deletion cost is determined based on a second predetermined semantic cost and a salience of the second word; and

the substitution cost is determined based on a salience of the third word, a salience of the fourth word, a semantic similarity between the third word and the fourth word in the semantic space, the first predetermined semantic cost, and the second predetermined semantic cost.

7. The method according to claim **6**, wherein:

the salience of the first word is based on a frequency of occurrence of the first word in a first corpus;

the salience of the second word is based on a frequency of occurrence of the second word in the first corpus;

the salience of the third word is based on a frequency of occurrence of the third word in the first corpus; and

the salience of the fourth word is based on a frequency of occurrence of the fourth word in the first corpus.

8. The method according to claim **7**, wherein the first corpus comprises a plurality of categories that includes a plurality of text phrases, and wherein:

the salience of the first word is based on a proportion of the plurality of categories that include the first word;

the salience of the second word is based on a proportion of the plurality of categories that include the second word;

the salience of the third word is based on a proportion of the plurality of categories that include the third word; and

the salience of the fourth word is based on a proportion of the plurality of categories that include the fourth word.

9. The method according to claim **6**, wherein:

the salience of the first word is based on a normalized entropy of the first word in a second corpus;

the salience of the second word is based on a normalized entropy of the second word in the second corpus;

the salience of the third word is based on a normalized entropy of the third word in the second corpus; and

the salience of the fourth word is based on a normalized entropy of the fourth word in the second corpus.

10. The method according to claim **6**, wherein:

the salience of the first word is based on whether a first predetermined list of sensitive words includes the first word;

the salience of the second word is based on whether a second predetermined list of sensitive words includes the second word;

the salience of the third word is based on whether a third predetermined list of sensitive words includes the third word; and

the salience of the fourth word is based on whether a fourth predetermined list of sensitive words includes the fourth word.

11. The method according to claim **1**, further comprising:

determining a centroid distance between a centroid position of the first text phrase in the semantic space and a centroid position of the second text phrase in the semantic space, wherein the degree of semantic similarity between the first text phrase and the second text phrase is based on the centroid distance.

12. The method according to claim **11**, wherein the centroid position of the first text phrase is determined based on a semantic position of one or more words of the first text phrase in the semantic space and the centroid position of the second text phrase is determined based on a semantic position of one or more words of the second text phrase in the semantic space.

13. The method according to claim **11**, wherein the centroid position of the first text phrase is determined based on a salience of one or more words of the first text phrase and the centroid position of the second text phrase is determined based on a salience of one or more words of the second text phrase.

14. The method according to claim **11**, wherein the degree of semantic similarity is based on a linear combination of the semantic edit distance and the centroid distance.

15. The method according to claim **1**, wherein the degree of semantic similarity is based on whether the first text phrase includes a fifth word that the second text phrase does not include and whether a predetermined list of keywords includes the fifth word.

16. The method according to claim **1**, wherein the semantic space is derived from a second corpus that includes a plurality of text phrases, and wherein each text phrase of the plurality of text phrases includes less than 150 characters.

17. A method for processing natural language comprising:

at an electronic device:

receiving a first text phrase;

determining one or more word-level differences of the first text phrase with respect to a second text phrase, wherein the one or more word-level differences include one or more of:

a first word-level difference comprising the second text phrase including a first word that does not correspond to any word of the first text phrase;

a second word-level difference comprising the first text phrase including a second word that does not correspond to any word of the second text phrase; and

a third word-level difference comprising the first text phrase including a third word that is different from a corresponding fourth word of the second text phrase;

determining a total semantic cost associated with the one or more word-level differences based on one or more of:

a salience of the first word;

a salience of the second word;

a salience of the third word;

a salience of the fourth word; and

a semantic similarity between the third word and the fourth word in a semantic space;

wherein a degree of semantic similarity between the first text phrase and the second text phrase is based on the total semantic cost;

determining, based on the degree of semantic similarity between the first text phrase and the second text phrase, a first intent associated with the first text phrase; and

performing, based on the first intent, a task associated with the first text phrase.

18. A non-transitory computer-readable storage medium comprising computer-executable instructions for causing a processor to:

receive a first text phrase;

determine whether editing the first text phrase to match a second text phrase requires one or more of:

insert a first word into the first text phrase, wherein the second text phrase includes the first word;

delete a second word from the first text phrase; wherein the first text phrase includes the second word; and

substitute a third word of the first text phrase with a fourth word, wherein the second text phrase includes the fourth word;

in response to determining that editing the first text phrase to match the second text phrase requires one or more of inserting the first word into the first text phrase, deleting the second word from the first text phrase, and substituting the third word of the first text phrase with the fourth word, determining one or more of:

an insertion cost associated with inserting the first word into the first text phrase;

a deletion cost associated with deleting the second word from the first text phrase; and

a substitution cost associated with substituting the third word of the first text phrase with the fourth word;

determine, based on the one or more of the insertion cost, the deletion cost, and the substitution cost, a semantic edit distance between the first text phrase and the second text phrase in a semantic space, wherein a degree of semantic similarity between the first text phrase and the second text phrase is based on the semantic edit distance;

determine, based on the degree of semantic similarity between the first text phrase and the second text phrase, a first intent associated with the first text phrase; and

perform, based on the first intent, a task associated with the first text phrase.

19. An electronic device comprising:

one or more processors;

memory; and

one or more programs, wherein the one or more program are stored in the memory and configured to be executed by the one or more processors, the one or more programs including instructions for:

receiving a first text phrase;

determining whether editing the first text phrase to match a second text phrase requires one or more of:

inserting a first word into the first text phrase, wherein the second text phrase includes the first word;

deleting a second word from the first text phrase; wherein the first text phrase includes the second word; and

substituting a third word of the first text phrase with a fourth word, wherein the second text phrase includes the fourth word;

in response to determining that editing the first text phrase to match the second text phrase requires one or more of inserting the first word into the first text phrase, deleting the second word from the first text phrase, and substituting the third word of the first text phrase with the fourth word, determining one or more of:

an insertion cost associated with inserting the first word into the first text phrase;

a deletion cost associated with deleting the second word from the first text phrase; and

a substitution cost associated with substituting the third word of the first text phrase with the fourth word;

determining, based on the one or more of the insertion cost, the deletion cost, and the substitution cost, a semantic edit distance between the first text phrase and the second text phrase in a semantic space, wherein a degree of semantic similarity between the first text phrase and the second text phrase is based on the semantic edit distance;

determining, based on the degree of semantic similarity between the first text phrase and the second text phrase, a first intent associated with the first text phrase; and

performing, based on the first intent, a task associated with the first text phrase.

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